DIETARY INTAKE OF CANADIANS IN ASSOCIATION WITH METABOLIC SYNDROME, DIABETES, AND RISK OF CARDIOVASCULAR DISEASE

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By

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ABSTRACT

Cardiovascular disease (CVD) is second leading cause of death in Canada. Diabetes is a major risk factor for CVD, which is affecting more than 7.5% of Canadians. Prevention is important to reducing the burden of diabetes and CVD on the individual, society and health care sector. In order to prevent these diseases, identifying people at high risk and using modifiable factors in prevention of these diseases are the priority. The metabolic syndrome (MetS), CVD risk and cardiovascular age gap (CAG) are concepts, which have been recommended by national health organizations for identifying individuals with high risk of developing these diseases. Diet has been recognized as an important modifiable factor in the prevention of metabolic disorders, diabetes and CVD. The aim of the present thesis was to determine the prevalence of diabetes, MetS components, MetS and the mean risk of 10-year atherosclerotic cardiovascular disease (ASCVD) and CAG. Further, the association between MetS, 10-year ASCVD risk and CAG and dietary patterns among Canadian adults were determined. The Canadian Health Measures Survey (CHMS) combined Cycles 1 & 2 (2007-11) data were used to address these research objectives.

In CHMS, the FFQ was used to determine the usual dietary intake among Canadians. Principal component analysis method was applied to extract the dietary patterns from 32 food/food groups available from CHMS data. Controlling for potential covariates, logistic and linear regression was used to determine the association between MetS, 10-year ASCVD risk and CAG and dietary patterns. To produce nationally representative results, weighting and bootstrapping were applied.

The MetS prevalence was 16.9% among a sample representative of 26,038,108 Canadians aged 12-79 years. Four prevalent dietary patterns were extracted and the "Fast food" dietary pattern with positive loadings of hotdogs, sausage/bacon, chips, fries, and diet soft drinks, had a significant association with MetS (odds ratio=1.26; 95% CI: 1.016 to 1.55; p=0.035) for older adults aged 50-79 year.

The mean 10-year ASCVD risk was 6.9% for a sample representative of 13,655,671 Canadians aged 40-79y. The mean vascular age for men was 4.1 years older and for females was 0.4 years younger than their chronological age. Four dietary patterns emerged from this population of 40-79 years. Of note, the "High carbohydrate and protein" dietary pattern, which included potatoes, red meat, sausage, egg and ice-cream/frozen yoghurt, was adversely associated with 10-year ASCVD (P_{trend}= 0.0128). Further, the "Healthy" and "Fast food" dietary patterns had an inverse ($p<0.0001$) and direct ($p=0.005$) association, respectively, with CAG adjusted for potential covariates.

A considerable portion of Canadian adults had high relative and absolute ASCVD risk. Dietary patterns prevalent among the population that were associated with MetS, CAG and ASCVD 10-year risk were unhealthy. Thus, interventions with focus on educating Canadians, especially high-risk groups, with the aim of promoting a healthier balanced diet, along with increasing the physical activity and stop/preventing smoking, should be considered by researchers.

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LIST OF ABBREVIATIONS

ACC	American College of Cardiology
AHA	American Heart Association
AMDR	Acceptable Macronutrient Distribution Range
ASCVD	Atherosclerotic cardiovascular disease
ATP-III	Adult Treatment Panel III
BMI	Body mass index
CCHS	Canadian Community Health Survey
CFA	Confirmatory factor analysis
CHD	Coronary heart disease
CHMS	Canadian Health Measures Survey
CCSG	Canadian Cardiovascular Society Guidelines
CAG	Cardiovascular age gap
CVA	Cardiovascular age
CVD	Cardiovascular diseases
DASH	Dietary Approaches to Stop Hypertension
DEE	Daily leisure-time energy expenditure
DGA	Dietary Guidelines for Americans
EGIR	European Group for the Study of Insulin Resistance
FFA	Free fatty acids
FFQ	Food frequency questionnaire
FHS	Framingham Heart Study
FRS	Framingham Risk Score
HbA1c	Glycated hemoglobin A1c
HDL-C	High-density lipoprotein cholesterol
HEI	Healthy Eating Index
IDF	International Diabetes Federation
MEC	Mobile examination center
MetS	Metabolic syndrome
NCEP	National Cholesterol Education Program
NHANES	National Health and Nutrition Examination Surveys
NHLBI	National Heart Lung and Blood Institute
OGTT	Oral glucose tolerance test
PCA	Principle component analysis
PLS	Partial least square regression
RCT	Randomized controlled trial
RRR	Reduced rank regression

SCORE	Systematic Coronary Risk Evaluation
SSB	Sugar-sweetened beverages
WHO	World Health Organization

CHAPTER 1: Introduction

1.1. Background Information and Rationale

Two main causes of death in Canada are cardiovascular disease (CVD) and diabetes[1] (Statistics Canada, 2018). It is essencial to understand the underlying risk factors linked to these non-communicable diseases on the one hand and to detect the population at high risk for these diseases on the other hand. The metabolic syndrome (MetS) and CVD risk assessment tools including 10-year atherosclerotic cardiovascular disease (ASCVD) risk assessment and cardiovascular age gap (CAG) are developed to assess the relative and absolute risk of CVD, respectively.

If at least three of the five MetS components as follows, elevated blood pressure, fasting plasma glucose, triglycerides, waist circumference, and reduced high-density lipoprotein cholesterol (HDL-C) are present, MetS is diagnosed in the individual (Alberti, Eckel, Grundy, Zimmet, Cleeman, Donato, Fruchart, James, et al., 2009). Having MetS increases the risk of developing CVD and diabetes, however, whether it is a different risk than the joint effect of the components still remains as a controversy (Beck-Nielsen, 2013).

The CVD risk assessment and CAG are tools represented by researchers conducting cohort studies such as the Framingham Heart Study (FHS) with the aim of identifying high-risk individuals/groups within the population (D'Agostino et al., 2008). The absolute CVD risk is the probability of a person developing CVD over a certain period of time (Goff et al., 2014). The CAG is the difference of chronological age and vascular age. The vascular age is the age of one who has similar predicted risk but with all the risk factors being normal (D'Agustino, 2008).

Findings of cohort and cross-sectional studies show that diet is an important factor in the prevention and development of MetS and CVD (Calton, James, Pannu, & Soares, 2014; Williams et al., 2000). According to the 2013 American Heart Association (AHA) /American College of Cardiology (ACC) Lifestyle Management Guideline, diet-based plans have a major role in preventing metabolic disorders and CVD (Eckel et al., 2014). The key components of these recommendations are a dietary pattern with the following characteristics: high intakes of

[1] In this proposal diabetes includes only diabetes type 2.

fruits, vegetables and whole grains, fish, legumes, poultry, low-fat dairy products and nuts and limiting sweets, sugar-sweetened beverages (SSB), red meat and sodium (Eckel et al., 2013). To reduce the risk of developing CVD, a diet rich in whole grains, vegetables and fruits, low in cholesterol and saturated fats, and limited in alcohol is recommended (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001; Hu, 2002; Nitzke & Freeland-Graves, 2007; Sonnenberg et al., 2005). While the intake of food groups such as dairy products (Azadbakht, Esmaillzadeh, Azizi, & Mirmiran, 2005) and fruits and vegetables (Esmaillzadeh et al., 2006) has been found to have an inverse association with MetS, the intake of SSB and diet soft drinks has been found to be significantly more prevalent in individuals with MetS (Lutsey, Steffen, & Stevens, 2008). However, inconsistent results have been observed in the literature regarding the intake of food groups such as grains and vegetables and fruit and their relationship with MetS (Esmaillzadeh et al., 2006; Lutsey et al., 2008; Ruidavets et al., 2007; Setayeshgar, Whiting, & Vatanparast, 2012). Overall, these health complications have multiple underlying risk factors. To understand their association with diet, investigating dietary patterns, as a holistic perspective into diet would be more beneficial compared to single nutrients. The association between CVD risk and CAG and dietary patterns has yet to be determined in Canada.

The relationship between dietary patterns and MetS has been studied in different populations around the world. While an inverse association between the Mediterranean diet and MetS has been mainly observed (Panagiotakos, Pitsavos, & Stefanadis, 2009; Rumawas, Meigs, Dwyer, McKeown, & Jacques, 2009), a direct relationship was found between the so-called "Western" dietary pattern and MetS (Denova-Gutiérrez et al., 2010; Lutsey et al., 2008; Martínez-González et al., 2011). Furthermore, inconsistent results have been reported between a "Healthy" dietary pattern, Healthy Eating Index (HEI) scores or Dietary Guidelines for Americans Index scores and MetS (Fogli-Cawley et al., 2007; Pimenta et al., 2014). It is beneficial to investigate these associations among the population in order to make the appropriate policies for the ultimate goal of reducing the risk of CVD among the population. In addition, research is required to understand the gaps of knowledge for such associations in the literature.

The Canadian Health Measures Survey (CHMS) is a nationally representative health survey conducted by Statistics Canada in collaboration with Health Canada and the Public Health Agency of Canada. In CHMS, data are collected via interviews and direct physical measurements such as blood measurements making CHMS a unique survey. CHMS Cycles 1 and 2 took place from 2007 to 2009 and 2009 to 2011, respectively, and their data have been released (Statistics Canada, 2011). According to a recent study based on CHMS Cycle 1 data, the prevalence of MetS in the Canadian population was 18.31 % for ages 12-79 years (Setayeshgar et al., 2012). This study showed that individuals with MetS consumed significantly more diet soft drinks than individuals without MetS. Due to the cross-sectional nature of the study, it remained unclear whether or not this result was a consequence of individuals with diabetes adherence to a recommended diet of having beverages with lower sugar content. In another study, based on the same survey data, the estimated mean of Canadians' 10-year CVD risk was 9.86 % (Setayeshgar, Whiting, & Vatanparast, 2013). In these studies, based on CHMS Cycle 1 data, a low statistical power as a result of small sample size was considered as the main limitation for their study. The dietary pattern of Canadians using this survey has yet to be determined. This survey provides information for investigating the association of MetS and CVD risk and dietary patterns for the Canadian population.

The present study has the advantage of using CHMS Cycle 1 and 2 data, which provides two main opportunities. First, combining survey data from more than one cycle increases the sample size, strengthens the statistical analysis and reduces the sampling error (Schenker & Raghunathan, 2007). Therefore, an approach that combines survey data from different cycles of CHMS is considered more efficient in terms of statistical power compared to a single survey. Second, CHMS provides usual dietary intake data on the one hand and objective measures of health outcomes on the other hand. To our knowledge, the relationship of MetS, diabetes, CVD risk, and CAG with diet and dietary patterns have not been evaluated before for the Canadian general population.

1.2. Purpose of Study

The aim of the present thesis was to investigate the prevalence of MetS, diabetes (diagnosed, pre-diabetes (impaired fasting glucose/impaired glucose tolerance/glycated hemoglobin HbA1c (HbA1c) of 6.0-6.4%,) and undetected diabetes), CVD risk and CAG in the population and determine their relationships with diet using data from two consecutive CHMS cycles (conducted from 2007 to 2011). The Canadian population's dietary patterns and intake from food groups were assessed. This research focused on the Canadian population, taking into account demographics, socio-economic status, and lifestyle factors.

1.3. Study Title, Objectives, and Statement of Hypotheses

Study 1 title: "Current evidence on the association between metabolic syndrome and dietary patterns in a global perspective."

Objective 1: To critically evaluate the current evidence on the association between MetS and dietary patterns in a global perspective.

To address Objective 1, a web-based scoping review of the current evidence on the association between MetS and the different dietary patterns were conducted using the framework provided by Arksey and O'Malley (2005).

Study 2 title: "Canadians dietary intake from 2007-2011 across different socio-demographic/lifestyle factors using the Canadian Health Measures Survey Cycles 1&2."

Objective 2: To determine Canadians' consumption from different food groups by demographics, socioeconomic status and lifestyle factors using combined data from CHMS Cycles 1 and 2 (ages 12 to 79 years).

To address Objective 2, the Canadians' dietary status by demographics, socioeconomic status, and lifestyle factors was determined using the combined data from CHMS Cycles 1 and 2 (ages 12-79 y).

Hypothesis: we hypothesized that females have greater intakes of fruit and vegetables and lower intake of SSB. The intake of fruit and vegetables are greater for higher income and education level groups.

Study 3 title: "The prevalence of type 2 diabetes among Canadian adults and association with socio-demographic factors and dietary habits using nationally representative Canadian Health Measures Survey."

Objective 3: To evaluate the prevalence and determinants of diabetes and to determine whether the diet of known-cases (diagnosed) of diabetes is different from the diet of undiagnosed cases of diabetes.

To address Objective 3, the prevalence of diagnosed and undiagnosed (undetected) diabetes and prediabetes status by demographics, socioeconomic status and lifestyle factors at the national level between years 2007 to 2011 were determined (for ages 20 to 79 years). Further, the difference in intake from food/food groups comparing individuals with diagnosed diabetes and the rest of the population were evaluated (20-79y).

Hypothesis: We hypothesized that diagnosed diabetes, undetected diabetes and prediabetes are more prevalent among groups with lower socio-demographic and lifestyle levels including income, education and physical activity factors.

Study 4: "Fast food" dietary pattern increases the risk of metabolic syndrome among Canadian older adults regardless of body mass index (BMI), Canadian Health Measures Survey 2007-11."

Objective 4: To determine the prevalence and determinants of MetS, its components by demographics, socioeconomic status and lifestyle factors at the national level between years 2007 to 2011 (for ages 12 to 79 years). Furthermore, we aimed to assess the association between MetS and intake from food groups and dietary patterns.

Hypothesis: We hypothesized that the prevalence of MetS is higher in Canadians with lower income and education levels and Canadians who are inactive, frequent alcohol users and smokers. Individuals with MetS have less healthy dietary patterns and consume less vegetable and fruits and milk and alternatives than other Canadians.

Study 5: "Risk of atherosclerotic cardiovascular disease and cardiovascular age gap and their association with diet among Canadian adults 40-79 years, the cross-sectional Canadian Health Measures Survey 2007-11."

Objective 5: To evaluate the prevalence and determinants of ASCVD risk and CAG by demographics, socioeconomic status and lifestyle factors at the national level between years 2007 to 2011 using combined data from CHMS Cycles 1 and 2 (ages 12 to 79 years). Further, to determine the association between diet status and ASCVD risk and CAG.

To address Objective 5, the prevalence of ASCVD risk and CAG (ages 40 to 79 years) by demographics, socioeconomic status, lifestyle, metabolic and medication using factors at the national level between years 2007 to 2011 were evaluated. Furthermore, the associations between CVD risk and CAG and intake from and dietary patterns were assessed.

Hypothesis: We hypothesized that the mean risk of 10-year ASCVD and mean CAG are higher for groups in the lower socioeconomic status and lifestyle levels. Those with high 10-year ASCVD risk have a less healthy dietary pattern.

1.4. Significance of the Studies

It is important to identify people at risk for diabetes and CVD and to know the association between modifiable lifestyle factors and the risk of these diseases. In CHMS, data are collected via interviews, physical and clinical measurements, making CHMS a unique survey.

While comprehensive national food frequency intake data are provided by CHMS, to our knowledge no attempt has been made to understand dietary patterns via this data set among Canadians. More importantly, this dataset provides an opportunity to investigate the associations between diet and MetS, CVD risk and diabetes. Greater knowledge of Canadians' dietary patterns and association with the aforementioned health complications will help policymakers in determining health policy decisions.

1.5. Thesis Outline

The outline of the thesis is demonstrated in Table 1.1. This thesis includes 9 Chapters, Chapters 2 and 3 are literature review and a Scoping review (Study 1), respectively, of the current knowledge and research around the topic of this thesis. In Chapter 4, the general methodology of this thesis is explained. We included the results of Studies 2 to 5 in Chapters 5 to 8, respectively. Chapter 9 is the final chapter of this thesis, which links the findings of this study together and includes limitations and gaps of our studies.

Table 1. 1. Ph.D. thesis outline of Studies 1 to 5.

Study #	Objective	Short title
Study 1	1	Scoping review of MetS and dietary patterns worldwide
Study 2	2	Dietary intake of Canadians 2007-11
Study 3	3	Diabetes status of Canadian adults and their dietary intake
Study 4	4	Determining the association between MetS and dietary patterns of Canadians (ages 12-79y).
Study 5	5	Determining CVD risk and CAG among Canadians and their association with dietary patterns (ages 40-79y)

CVD, cardiovascular diseases; MetS, metabolic syndrome; CAG, cardiovascular age gap

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CHAPTER 2: Literature Review

2. 1. Metabolic Syndrome

CVD and diabetes have been major causes of death in the past decade worldwide (World Health Organization (WHO), 2016). It is essential to understand the underlying risk factors related to these two highly prevalent non-communicable diseases to be able to reduce the risk of related morbidity and mortality events. The MetS is a cluster of important risk factors related to CVD and diabetes (Esposito et al., 2004). MetS is determined as a metabolically abnormal status that constitutes glucose intolerance, dyslipidemia, hypertension, pro-inflammatory and pro-thrombotic state (Kaur, 2014). At the clinical level, according to the joint statement by the International Diabetes Federation (IDF) and the AHA/National Heart, Lung, and Blood Institute MetS is diagnosed as having three or more of these CVD-related risk factors including central obesity, hyperglycemia, dyslipidemia (including hypertriglyceridemia and lowered HDL-C) and hypertension (Alberti et al., 2009).

The concept of clustering of risk factors related to CVD originated from the early 1920s by a Scandinavian researcher indicating the presence of a relationship between metabolic abnormalities such as hypertension and hyperglycemia (Kaur, 2016; Kylin, 1923). Other researchers touched this concept slightly until 1988, through the Banting Lecture titled “Role of insulin resistance in human disease”, wherein Gerald Reaven described the importance of insulin resistance in the etiology of type 2 diabetes and coronary heart disease (CHD) (Reaven, 1988). Reaven noted that insulin resistance, glucose intolerance, hyperinsulinemia, hypertriglyceridemia, decreased HDL-C and hypertension are related factors that are often observed together. He called this constellation of CVD risk factors the “syndrome X” (Reaven, 1988). Ten years after Reaven’s Banting Lecture, WHO used the term “metabolic syndrome” (WHO, 1999). The prevalence reported for the MetS across the globe ranges from less than five to more than 80 percent (Grundy, 2008). This wide variability in prevalence that has been reported is likely due to different ages, sex, MetS criteria, and ethnic backgrounds of subjects.

Individuals with MetS have two to five times higher risk of developing CVD and diabetes compared with individuals with no MetS (Alberti et al., 2009). However, whether it is the effect of MetS as a whole concept or it is the summation effect of its components that is increasing the risk of CVD, still requires more investigation (Eckel, Alberti, Grundy, Zimmet, 2010). According to a meta-analysis of 43 longitudinal studies, for individuals with MetS, the relative risk of developing CVD is 1.78 times greater than the risk for those without MetS (Gami et al., 2007). The consequences of MetS (diabetes and CVD) place a huge burden on the health care system. Therefore, it is important to consider MetS as one diagnostic indicator of these two non-communicable epidemic diseases of diabetes and CVD. It is essential to consider the epidemiological perspective of MetS to be able to suggest and implement proper preventive interventions for MetS among the Canadian population.

Statistics show a rising trend for MetS in Western countries, which, unsurprisingly, has been increasing side to side with abdominal obesity (Kassi et al., 2011). In Canada, the prevalence of abdominal obesity alone was estimated to be 37% and 13% among adults and adolescents, respectively, in 2007-2009 based on CHMS Cycle 2 (Janssen, 2013). In 2006, the direct cost of obesity to the health care system was $3.9 billion (Janssen, 2013).

The prevalence of MetS in the Canadian population has been investigated in several studies. In a study based on the Canadian Heart Health Survey data between the years of 1986 and 1992, the prevalence of MetS amongst 18- to 64-year-old participants was measured (MacPherson, de Groh, Loukine, Prud'homme, & Dubois 2016). The researchers replaced BMI with waist circumference as one of MetS components. As well, a self-reported diagnosis of diabetes was used for the fasting plasma glucose component of MetS. The results of this study indicated a prevalence rate of 14.4% for MetS among Canadian adults (Brien & Katzmarzyk, 2006). Based on the first three consecutive cycles of CHMS, the prevalence of MetS among Canadian adults was reported to be 18.3%, 22% and 21% in 2007/2009, 2009/2011 and 2012/2013, respectively for a ages 12-79 years (Setayeshgar, Whiting & Vatanparast, 2012; Statistics Canada, 2013a; Statistics Canada, 2015a). These studies have used the MetS harmonized definition for adults (Alberti et al., 2009). The MetS definitions and the CHMS cycles are described in detail in sections 2.1.2 and 2.4.1, respectively.

2.1.1. Metabolic Syndrome Pathogenesis

In his 1988 Banting Lecture, Gerald Reaven had emphasized on the role of insulin resistance as the significant factor in the pathophysiology of Syndrome X. As he had observed insulin resistance in non-obese individuals, he initially did not indicate obesity as a feature nor a component of this syndrome (Després et al., 2008). Later, researchers had observed central obesity in most patients with MetS; therefore, they suspected central obesity as the underlying causative factor for this syndrome. These findings led researchers to debate on the main features of MetS pathogenesis (Grundy, 2015). However, there are also other factors that contribute to the appearance of this syndrome including, age, physical activity, genes and pro-inflammatory state (Després et al., 2008).

The role of insulin resistance is supported by studies that found insulin resistance mostly present with a constellation of metabolic abnormalities (Alberti, 2006). Insulin impacts the status of glucose and is also involved in other body regulatory processes such as regulating plasma non-esterified free fatty acids (FFA). Resistance to insulin at the cellular level to regulate the absorption of glucose leads to the compensatory action of pancreatic beta cells to prevent hyperglycemic state. However, in many individuals, this compensation is not maintained for a long time and contributes to the development of type 2 diabetes. Moreover, this hyperinsulinemic state contributes to an increase in blood pressure, by insulin's action on renal sodium reabsorption. The latter is followed by water reabsorption in the kidneys and increases in blood volume leading to an increase in the blood pressure. Furthermore, insulin resistance in the adipocytes reduces lipolysis insulin suppression and thus the FFA flux increases. The increased FFA flux to the hepatic site induces atherogenic dyslipidemia (Godsland and Stevensen, 1995).

Although the importance of insulin resistance in the pathogenesis of MetS is demonstrated, the constellation of metabolic abnormalities is mainly found in abdominally obese individuals (Grundy, 2015). Since central obesity is found to be associated with all of the metabolic abnormities of MetS, it has been hypothesized as the underlying pathophysiological factor of the syndrome (Figure 2.1.). Further, the

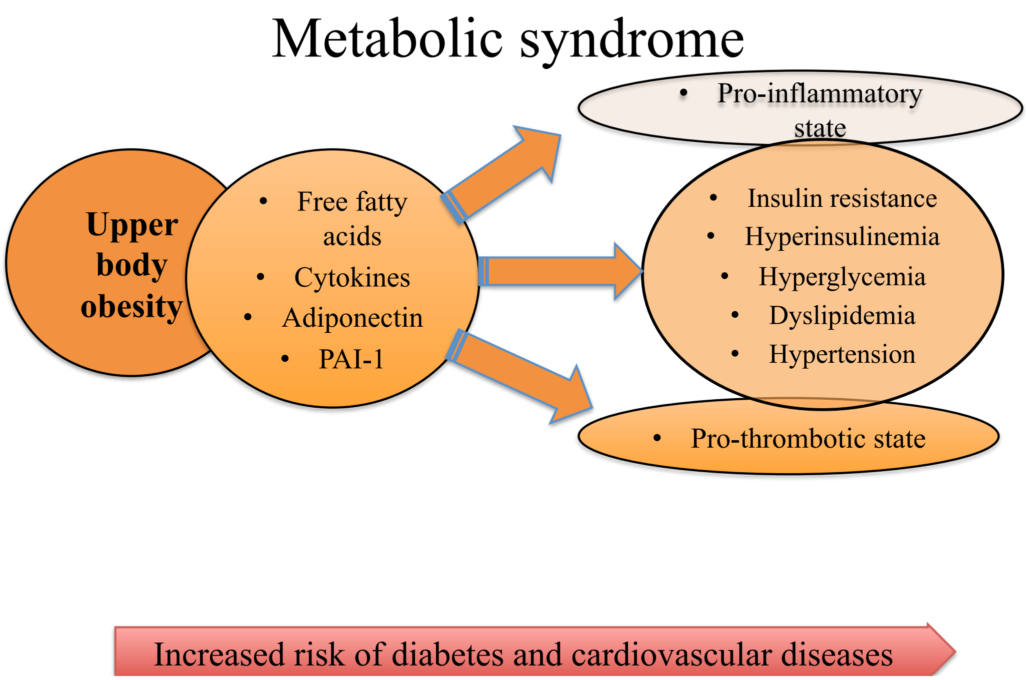

Figure 2. 1 Pathophysiology of metabolic syndrome. (PAI-1: plasminogen activator inhibitor type 1)

importance of adipose tissue is due to its role in the development of ectopic fat, which is the main contributor to the metabolic abnormalities. The importance of abdominal obesity and more specifically visceral adipose tissue came to attention when imaging techniques such as computed topography revealed the abundance of visceral adipose tissue in patients with metabolic abnormalities compared to individuals with similar BMI and absence of metabolic abnormalities (Després and Lemieux, 2006).

One hypothesis that supports visceral adipose tissue as an underlying feature of MetS is the “fatty acid theory”. Based on this theory the adipocytes distribution in the body determines the volume of the FFA flux and consequently the development of ectopic fat (Grundy, 2015). The higher distribution of adipose tissue in the upper body leads to high FFA flux that contributes to skeletal muscle insulin resistance, hyperinsulinemia and atherogenic dyslipidemia leading to ectopic fat accumulation (Grundy, 2015).

Another hypothesis for the role of central obesity in the development of MetS is the endocrine function of the adipose tissue. This tissue releases different adipokines such as inflammatory cytokines, plasminogen activator inhibitor-1, adiponectin and leptin (Grundy, 2015). Adipokines including the inflammatory cytokines and plasminogen activator inhibitor-1 contribute to the pro-inflammatory and pro-thrombotic state associated with MetS, respectively (Grundy, 2015 & 2016). Moreover, in viscerally obese subjects, a reduction in plasma levels of adiponectin protein is observed. This protein originates from the adipose tissue. In vitro studies have indicated the significant role of adiponectin in optimizing insulin sensitivity and protection against atherosclerosis (Grundy, 2016). The aforementioned theories of the MetS pathogenesis have led researchers to define criteria for MetS in order to investigate it at the clinical or population level. These criteria are discussed in the next section.

2.1.2. Metabolic Syndrome Clinical Criteria

The importance of MetS in the occurrence of diabetes and CVD has led researchers to identify a set of criteria for this syndrome at the clinical level. In the past 20 years, the world's health-related organizations have proposed different clinical diagnostic criteria for MetS (Table 2.1). The risk factors, which are included in different criteria, are related to the aforementioned hypothesis regarding the pathogenesis of the syndrome. They include BMI/waist circumference, insulin resistance, blood pressure, HDL-C, fasting blood sugar and triglyceride levels (Alberti et al., 2006). The WHO and the European Group for the Study of Insulin Resistance (EGIR) include insulin resistance as a diagnostic criterion (in addition to albumin/creatin ratio for WHO); however, the Adult Treatment Panel III (ATP III) of the National Cholesterol Education Program (NCEP), IDF, and the AHA/National Heart Lung and Blood Institute (NHLBI) definitions excluded the insulin resistance component (Table 3.1). Moreover, all definitions, except for the WHO definition, include waist circumference elevated cut-points for as an indicator of abdominal obesity (Alberti, 2006).

Since the abovementioned criteria were proposed, researchers evaluated their predictive power in different studies. A longitudinal study of participants in the San Antonio Heart Study demonstrated that the NCEP-ATPIII definition predicted type 2 diabetes more accurately than the WHO definition (Lorenzo, Okoloise, Williams, Stern, & Haffner, 2003). In the Malmö Diet and Cancer study, the IDF, NCEP-ATP III, and EGIR definitions were used to measure MetS and predict CVD in an 11-year follow-up period. The results of this study conducted on 5,047 patients indicated that a higher prevalence of MetS was obtained with the IDF (21.9%) definition when compared to the NCEP-ATP III (20.7%) and EGIR (18.8%) definitions. However, the IDF definition did not predict CVD better than the other two definitions (Nilsson, Engström, & Hedblad, 2007).

Finally, in 2009, a joint scientific statement agreement between several health expert groups including the IDF and AHA/NHLBI was published (Table 2.1). This group presented a unified definition of MetS as having at least three of the following five risk factors: waist circumference of above the ethno-specific cut-points, increased triglycerides (≥150 mg/dL or 1.7 mmol/L), increased blood pressure (≥ systolic 130 and/or diastolic 85 mm Hg), increased fasting glucose (≥ 100 mg/dL) and decreased HDL-C (< 40 mg/dL or 1.0 mmol/L for males and < 50 mg/dL or 1.3 mmol/L for females) (Alberti et al., 2009). Thus, in evaluating MetS in a multi-ethnic population such as Canada, these criteria would be useful.

2.1.2.1. Metabolic Syndrome in Adolescents

It has been shown that obesity and other components of MetS are related to CVD and that this relationship exists from the early stages of life and remains until adulthood (Rosenberg, Moran, & Sinaiko, 2005). Therefore, it is essential to identify and investigate the presence of MetS in children and adolescents (Rosenberg, 2005). In order to evaluate MetS in adolescents, it is important to consider the effect of puberty and age since, during puberty, fat distribution, anthropometrics, blood pressure and the pattern of insulin secretion are somewhat altered (Zimmet et al., 2007).

There are no unified criteria to evaluate MetS in very young people. Researchers working with adolescents have used different MetS definitions. These definitions were defined using arbitrarily chosen percentile cut-offs for each MetS component (Ford & Li,

Table 2.1. Metabolic syndrome criteria defined by different health authorities.

Criteria*	WHO (1999)	EGIR (1999)	NCEP ATP III (2001)	IDF (2005)	Joint Statement (2009)
Insulin resistance	IGT, IFG, T2DM, or lowered insulin sensitivity[*] plus any 2 of the following	Plasma insulin >75th percentile plus any 2 of the following	None, but any 3 of the following 5 features	None	None
Lipid	TG ≥150 mg/dL and/or HDL-C <35 mg/dL in men or <39 mg/dL in women	TG ≥150 mg/dL and/or HDL-C <39 mg/dL in men or women	TG ≥150 mg/dL HDL-C <40 mg/dL in men or <50 mg/dL in women	TG ≥150 mg/dL or on TG Rx HDL-C <40 mg/dL in men or <50 mg/dL in women or on HDL-C medication	TG ≥150 mg/dL or on TG Rx HDL-C <40 mg/dL in men or <50 mg/dL in women or on HDL-C medication
Blood pressure	≥140/90 mm Hg	≥140/90 mm Hg or on hypertension medication	≥130/85 mm Hg	≥130 mm Hg systolic or ≥85 mm Hg diastolic or on hypertension medication	≥130 mm Hg systolic or ≥85 mm Hg diastolic or on hypertension medication
Glucose	IGT, IFG, or T2DM	IGT or IFG (but not diabetes)	>110 mg/dL (includes diabetes)[‡]	≥100 mg/dL (includes diabetes)	≥100 mg/dL (includes diabetes)
Other	Microalbuminuria				

WHO, indicates World Health Organization; EGIR, European Group for the Study of Insulin Resistance; NCEP ATP III, National Cholesterol Education Program Adult Treatment Panel III; IDF, International Diabetes Federation, IGT, impaired glucose tolerance; IFG, impaired fasting glucose; T2DM, type 2 diabetes mellitus; BMI, body mass index; WC, waist circumference; TG, triglycerides; and HDL-C, high-density lipoprotein cholesterol.. *Adapted from Alberti et al (2006)

2008). The cut-points chosen arbitrarily by the researchers lacked health justifications. In 2007, the IDF definition for children and adolescents was proposed due to the lack of a consensus definition of MetS among children and adolescents (Zimmet et al., 2007). According to the IDF report, MetS can be defined in children from the age of 10 years. For children 10 to 16 years certain thresholds are considered, and for those above the age of 16 years, the adult criteria could be used.

2.1.3. Metabolic Syndrome and Ethnicity

Ethnicity is one factor that has been considered in evaluating MetS status due to its impact on different components, particularly central obesity, triglycerides and hypertension (Abate & Chandalia, 2011). One theory behind the relationship between ethnicity and MetS is that different ethnic groups with the same measures of central obesity have a different risk of CVD and diabetes. Therefore, it is important to consider suitable central obesity cut-points for different ethnicities (Abate & Chandalia, 2011).

The prevalence of MetS has been shown to vary among different ethnicities. Canada is a multicultural country with multiple ethnic groups. Hence, ethno-specific approach should be considered in studying MetS. A few studies have considered ethnic-specific criteria for abdominal obesity in determining Canadians MetS status. A study based on CHMS Cycle 1 data measured MetS using the 2005 IDF and AHA/NHLBI definition of MetS and the age/sex-specific MetS criteria for adults and adolescents, respectively. Moreover, in this study, an ethno-specific waist circumference was considered in measuring the abdominal obesity component for adults (Setayeshgar et al., 2012). The results indicated that MetS was prevalent among 19.6% and 3.5% of Canadian adults aged 19 to 79 years and adolescents, respectively (Setayeshgar et al., 2012). Recently, another study reported the MetS prevalence of Canadians 10 to 18 years to be 2.1% using combined data from the CHMS Cycles 1 and 2 (MacPherson et al., 2016).

In a study among the Aboriginal adult population in Canada, using the NCEP-ATP III criteria, MetS prevalence was 29.9% (Pollex, Hanley, Zinman, Harris, Khan, & Hegele, 2006). This result indicates the presence of a higher MetS prevalence among this ethnic group compared to other groups. The prevalence of MetS among native Canadian children and adolescents was assessed using ATP-III age-sex specific criteria (de Ferranti et al., 2004). The results of this study revealed that 18% of 10 to 19-year-old native Canadians have MetS (Retnakaran, Zinman, Connelly, Harris, & Hanley, 2006). Therefore, in evaluating MetS of multiethnic populations the

2005 IDF and AHA/NHLBI collaborative unified definition of MetS (Alberti et al., 2009) should be used, which considers ethnic diversity.

2.1.4. Diabetes Status Among Individuals with Metabolic Syndrome

The number of diabetic cases has been rising in Canada and throughout the world (IDF, 2015). Diabetic patients have a two to four times higher risk of CVD death compared to other individuals (Cheng & Barnes, 2013). In 2009, there were 2.4 million Canadians diagnosed with diabetes. The prevalence of diabetes is estimated to increase by nearly 50% from 2015 until 2025 (Diabetes Canada, 2015). This high number contributes to a high burden on the Canadian health care system.

An elevated level of fasting plasma glucose is considered as one of the manifestations of MetS (Table 2.2). Therefore, many individuals with MetS have pre-diabetes or diabetes. In addition, in MetS individuals with absent prediabetes and diabetes, there is an increased risk of developing diabetes (Punthakee, Goldenberg, & Katz, 2018). Thus, it is important that the government establishes strategies that prevent, diagnose and control this disease among the population.

Table 2. 2. Diagnosis of prediabetes.

Test	Range	Status
Fasting plasma glucose (mmol/L)	6.1-6.9	Impaired fasting glucose
Oral glucose tolerance test (mmol/L)	7.8-11.0	Impaired glucose tolerance
Glycated hemoglobin (%)	6.0-6.4	Prediabetes

Adapted from the Canadian Diabetes 2018 Guidelines (Punthakee, Goldenberg, & Katz, 2018).

In Canada, research has shown that individuals diagnosed with diabetes tend to adhere to special dietary recommendations by health professionals. In a study based on CHMS data, the individuals with MetS and known cases of diabetes had a significantly lower average fruit juice intake compared to MetS individuals with no diabetes (Setayeshgar et al., 2012). The latter group had included individuals with no diabetes in addition to individuals with undiagnosed diabetes (high fasting plasma glucose in the survey and non-diagnosis from health professionals) that did not know they actually have diabetes (Setayeshgar et al., 2012). Therefore, screening and diagnosis of diabetes can lead to positive modification of the diet towards a healthier diet and ultimately better health/disease status. Moreover, if individuals with diagnosed diabetes alter their diet; in evaluating the association between dietary intake and risk of chronic diseases at the population level, individuals with diagnosed diabetes should be evaluated separately.

2.2. Cardiovascular Disease

CVD includes the following diseases: CHD, cerebrovascular disease, peripheral arterial disease, rheumatic heart disease, congenital heart disease, deep vein thrombosis and pulmonary embolism (WHO-Europe, 2014). In addition, severe CVD includes stroke and heart attack (WHO-Europe, 2014). These disorders of the heart and blood vessels are the leading causes of death worldwide (WHO, 2016). The total CVD events are estimated to be around three times greater than CVD mortality (Reiner et al., 2011). Because this disease creates a burden for healthcare systems, it is essential to develop preventive approaches to reduce their incidence and eventually their prevalence in the population.

According to the Public Health Agency of Canada, CVD is any disease related to the circulatory system including the heart and vessels affecting any part of the body (Public Health Agency of Canada, 2010). In 2012, one in every four deaths was caused by heart disease and stroke (Statistics Canada, 2015b). CVD, being one of the leading causes of hospitalization in Canada, places a heavy burden on the health care system. These diseases account for annual direct and indirect costs of over $20.9 billion and, by 2020, are estimated to be over $28 billion (Conference Board of Canada, 2010).

Data from the Canadian Community Health Survey (CCHS) (2005) have shown the prevalence of self-reported heart disease in male and females 12 and older to be 4.3% and 2.9%, respectively. These numbers show a relative increase of 19% and 2%, respectively for men and women compared with statistics from 1994 (Lee et al., 2009). Hypertension and diabetes are among the risk factors that increased from 1994 to 2005. While the prevalence of smoking has decreased, the number of smokers in 2005 remained high, especially amongst the lower middle-income group (Lee et al., 2009). In 2007, the prevalence of heart disease was 4.2% and 5.3% for males and females above the age of 12 years, respectively, based on data from CCHS 2007 (Public Health Agency of Canada, 2009).

Epidemiological studies have been conducted since the 1940s to determine the risk factors and predictive measures of CVD. One such study was the Seven Countries Study. In this sex-specific cohort study, 12,763 men from different countries around the world were followed for 15 years beginning in 1958. Researchers investigated the relationship between lifestyle risk factors and CHD longitudinally. The results of this study indicated that factors such as dietary saturated fats, blood pressure and, more importantly, serum total cholesterol contribute to this relationship (Keys, 1980). The FHS was designed in 1947 by the NHLBI, starting with 5,209 men and women aged 30 to 62 years. This study revealed the impact of cholesterol, blood pressure, cigarette smoking, HDL-C, obesity, diabetes and socio-demographic risk factors on CVD (Wong, 2014). Following these epidemiological studies, many international heart studies have been conducted, including the Monitoring Trends and Determinants in Cardiovascular Disease project, INTERHEART, and Prospective Urban Rural Epidemiology study. National heart studies have also been conducted in many countries such as the British Whitehall study, the Iceland Reykjavik Heart Study, the German Prospective Cardiovascular Munster study and the American Atherosclerosis Risk in Communities Study (Wong, 2014).

Global CVD risk assessment methods are beneficial in terms of predicting CVD risk and; thereafter, establishing therapeutic or preventive strategies for the individual or population at risk (Setayeshgar, Whiting and Vatanparast, 2013). The epidemiological studies in this section have used different methods to assess CVD such as the CVD risk assessment tools, which is the focus of the next section.

2.2.1. Cardiovascular Disease Risk Assessment Tools

Researchers indicate that the MetS almost doubles the risk of developing CVD, which indicates a relative risk for CVD rather than an absolute risk (Leiter et al., 2011a). However, due to the fatal consequences and high global prevalence of CVD, it is important to measure the absolute risk itself. The absolute CVD risk is the probability of a person developing CVD over a certain period of time (Reiner et al., 2011). This risk can be obtained through algorithms or equations, which have been validated through cohort studies (Leiter et al., 2011a). Determining CVD as a risk or a “global risk” in a population would contribute to establishing preventive measures and validating therapeutic recommendations and guidelines (Beswick & Brindle, 2006; Wong, 2014). Therefore, many national and international health expert groups recommend the assessment of CVD risk (Goff et al., 2014; Punthakee, Goldenberg, & Atz, 2018; Anderson, 2016). The risk assessments developed by different studies and expert groups from the Framingham Risk Score (FRS) tool, Systematic Coronary Risk Evaluation (SCORE), “global cardiometabolic risk", 2012 Canadian Cardiovascular Society Guidelines (CCSG) and the 2013 ACC/AHA risk assessment tool are discussed in this section.

Since the 1950s, CVD risk assessment tools have been developed and used in different populations of the world (Beswick & Brindle, 2006). CVD has been known to result from a combination of "factors of risk," first mentioned in 1961 by the late director of the FHS (Kannel, Dawber, Kagan, Revotskie, & Stokes, 1961). In the early stages of the risk score development, epidemiological researchers stated that "the [CVD risk] function provides economical and efficient method for identifying persons at high cardiovascular risk who need preventive treatment and persons at low risk who need not [to] be alarmed about one moderately elevated risk characteristic" (Kannel, McGee, & Gordon, 1976, p.46).

2.2.1.1. The Framingham Risk Score Tool

The first FHS epidemiological study developed a method known as the FRS, which included multiple CVD risk factors to score the CVD risk (Kannel et al., 1976; Wong & Levy, 2013). The early equations of FRS included the following risk factors: age, sex, systolic blood pressure, serum cholesterol, cigarette smoking, glucose intolerance, and left ventricular hypertrophy. In 1991, the Framingham risk equation for predicting different CVD-related disease outcomes within different periods of time was presented. The risk factors included age, sex, blood pressure, total cholesterol to HDL-C ratio, glucose intolerance, smoking, and left ventricular hypertrophy (Anderson, Odell, Wilson & Kannel, 1991a). Later that same year an updated version of the equation was presented using a larger study population, including the original FHS and the Framingham Offspring Study respondents with an age range of 30 to 74 years. In this version prediction equations for several different CVD endpoints were presented (Anderson, Wilson, Odell & Kannel, 1991b). In 2001, the NCEP-ATP III recommended a new version of FRS that included the following risk factors: age, sex, smoking status, HDL-C, total cholesterol, and systolic blood pressure (and therapy). Every component of FRS is associated with a certain range of points (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001), and the sum of the points correspond to the individuals' risk of myocardial infarction and CHD death in the next 10 years. A risk of less than 10% is assumed as a low risk, between 10 to 20% is an intermediate risk and above 20% is considered as a high risk (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001; Wong, 2014).

The Framingham risk assessment function was applied to two German prospective study populations. The observed CHD incidence indicated that the risk assessment tool (Anderson et al., 1991b) overestimated the risk of CHD in the German population at least two times more than what was really observed (Hense, Schulte, Löwel, Assmann, & Keil, 2003). In a study in 2008, FRS was updated using as a population of 8,491 CVD-free FHS participants aged 30 to 74 years. The new equations were sex-specific and included the following risk factors: age, systolic blood pressure or hypertension therapy, HDL-C, total cholesterol, smoking, and diabetes (D'Agostino et al., 2008). Despite the prevalent application of the FRS by different researchers, however, this tool has some limitations. The FRS originated from a "White" population study (Goff et al., 2014) and it may underestimate the risk for women, youth, those from different ethnicities and individuals with MetS (Leiter et al., 2011a).

The 2012 CCSG recommends that the 2008 FRS method (D'Agostino et al., 2008) be used to identify CVD risk among men aged 40 to 75 and women aged 50 to 75 years. In addition, it is recommended to multiply the risk by a factor of two for individuals who have an immediate relative with a history of CVD before the age of 55 years for men and 65 years for women. The CCSG refers to this approach as the modified FRS approach (Anderson et al., 2013). According to the health program recommendations in Canada, it is beneficial to assess the CVD risk as an absolute risk measurement and along with CAG risk assessment tool (Anderson et al., 2013; Dasgupta et al., 2014). Researchers used the new risk assessment proposed by the CCSG in 2013, to estimate the risk of Canadians. Their results indicated a risk of 8.66% for Canadians 30-74 years in 2007/2009 (Setayeshgar et al., 2015).

2.2.1.2. The Systematic Coronary Risk Evaluation tool

In 2003, the European guidelines on CVD prevention in clinical practice recommended the SCORE method to estimate the total CVD risk for European countries (Graham et al., 2007). The SCORE method was developed based on pooled European cohort-designed studies. This method determined the 10-year risk of CVD death but not the risk of death from each type of CVD (death from stroke, etc) independently. The risk factors included age, sex, smoking, systolic blood pressure and total cholesterol (Graham et al., 2007). In the initial step of CVD risk evaluation, individuals with known CVD, very high levels of individual CVD risk factors or having diabetes with albuminuria were considered as cases with increased risk (Graham et al., 2007). Moreover, this method was updated as SCORE-HDL in 2009 by adding HDL-C as a risk factor in the algorithm. This modification reclassified patients into different risk categories, thus enabling more accurate CVD risk predictions (Halcox, Tubach, Sazova, Sweet, & Medina, 2013).

2.2.1.3. The Reynolds Risk Score tool

In 2007, a CVD global risk assessment tool named the Reynolds Risk Score specific to women was developed. This tool was validated in a U.S. cohort study of 24,558 women over the age of 45 years. The components of this age, total cholesterol, c-reactive protein, systolic blood pressure, HDL-C, smoking and family history of CVD. The researchers concluded that 40 to 50% of the individuals in the intermediate-risk category based on NCEP-ATP III version of FRS should be reclassified into the high and low-risk categories after applying these equations compared to results from the old equations (Ridker, Buring, Rifai, & Cook, 2007).

2.2.1.4. The Global Cardiometabolic Risk Assessment Tool

Traditional approaches such as the FRS do not include triglycerides or waist circumference, which are two important components of MetS, as risk factors (Leiter et al., 2011a, b). As a result, these risk assessment approaches may underestimate the risk for individuals with MetS. A new approach to assessing CVD risk is the “global cardiometabolic risk” developed by the Canadian Cardiometabolic Risk Working Group (Leiter et al., 2011a, b). This new approach not only includes traditional risk factors but also other important factors including MetS. In this approach, the CVD risk is multiplied by a factor of 1.5 to two if MetS is present in the individual. Therefore, this risk assessment method diminishes the underestimation of traditional risk factors (Leiter et al., 2011a, b). The different criteria used for determining MetS may lead to inconsistent risk results, which is a limitation of this method. The prevalence of 10-year CVD risk has been evaluated among Canadian respondents of the CHMS Cycle 1 cross-sectional study. The 10-year risk of developing CVD in the Canadian population aged 30 to 74 years was 9.86%. These researchers used the global cardiometabolic risk approach, and results showed a 1.76% increase compared to the risk obtained by the FRS traditional approach (8.1%). Age and level of education had direct and inverse associations with the risks measured, respectively. The researchers concluded that the traditional CVD risk assessment methods might underestimate the risk among the Canadian population (Setayeshgar et al., 2013).

2.2.1.5. The 2013 American College of Cardiology/American Heart Association Risk Assessment Tool

In 2013, the ACC/AHA recommended assessing the 10-year risk of ASCVD. This new CVD risk assessment approach was suitable for all individuals from 40 to 79 years with no previous ASCVD. The 2013 ACC/AHA report used data from observational studies representative of the U.S. population while considering hard ASCVD instead of CHD as the endpoint. Hard ASCVD included the first occurrence of one of the following incidents: non-fatal MI, CHD death, and stroke (fatal or non-fatal). To obtain the risk algorithms, the following pooled cohort studies were used: the Cardiovascular Health Study (Fried et al., 1991), the Atherosclerosis Risk in Communities Study (ARIC Investigators, 1989) and the Coronary Artery Risk Determinants in Young Adults study (Friedman et al., 1988), combined with applicable data from the original (Dawber, Kannel, & Lyell, 1963) and Offspring (Kannel, Feinleib, McNamara, Garrison & Castelli, 1979) Framingham Study cohorts. This risk-assessment tool presents the 10-year risk of hard ASCVD for non-Hispanic Whites and African American women and men aged 40 to 79 years (Goff et al., 2014). The risk factors included are as follows: age, systolic blood pressure (treated or untreated), HDL-C, total cholesterol, diabetes, and current smoking status. To obtain the risk for ethnicities other than African American and non-Hispanic Whites, the sex-specific equation for non-Hispanic Whites could be used. However, this approach could result in the overestimation of risk for Hispanics and Asian Americans. Additional research is required for other ethnicities to be specified (Goff et al., 2014).

According to the 2013 AHA/ACC report results from meta-analysis studies show that diabetes should be considered as a predictor variable for heart diseases rather than only assessing its developing risk as it is done for heart diseases. Therefore, diabetes is considered as a risk factor in the recent approach of ASCVD risk assessment presented by the 2013 AHA/ACC report (Goff et al., 2014).

Since 2013, some researchers have used the latest risk assessment approach proposed by the ACC/AHA guidelines reporting mixed results. The results of a study conducted among U.S. population, indicated a similar observed and predicted CVD risk among the population using the ACC/AHA pooled cohort risk equations (Muntner et al., 2014a). In addition, results from a multi-center international study indicated a better all-cause mortality prediction using the ACC/AHA risk assessment method compared to FRS and the NCEP ATP-III risk score (Cho et al., 2015). Researchers have predicted the risk of CVD for the U.S. Multi-Ethnic Study of Atherosclerosis study population. Five different risk assessment methods were used including the one proposed by the 2013 ACC/AHA guidelines. Results of this study indicated an overestimation of the risk after 10 years follow-up using all risk assessment criteria including the 2013 ACC/AHA risk assessment tool (Navar & Pencina, 2015). This overestimation could be due to factors such as healthy cohort effect, better preventive CVD therapies, incomplete reports of CVD events and a higher prevalence of healthier lifestyle that were not considered in the risk assessment tool (DeFilippis et al., 2015). In another cohort study that was conducted on a Dutch population, the CVD-related risk was assessed using three methods of 2013 ACC/AHA, the NCEP ATP-III and the European Society of Cardiology guidelines. Results of this study showed that all three methods had overestimated the risk (Kavousi et al., 2014). Researchers compared the risks predicted by the 2013 CCSG and the 2013 ACC/AHA risk assessment tools. Their results indicated an average risk of 12.4% versus 6.6% for the CCSG and the ACC/AHA risk assessment tools, respectively. One main reason for the difference observed between the risks is multiplying the risk for individuals with a family history of premature CVD (Hennessy, Bushnik, Manuel & Anderson, 2015).

Researchers have led discussions on the 2013 ACC/AHA guidelines ASCVD risk assessment approach. Ridker & Cook, (2013) have criticized this method indicating its 10-year risk ASCVD overestimation for five large cohorts (Ridker & Cook, 2013). However, the investigators of one of the mentioned cohorts have commented on this critical document and suggested explanations regarding this overestimation for the five cohort studies. These researchers explain that first, the large cohorts did not have active surveillance to identify all ASCVD incidents; second, the results of the baseline examination may have led the patients to start therapy; third, increased rate of revascularization which could contribute to less risk of MI incidence; and finally, the short follow-up period could have resulted in a low incidence and eventually an overestimation of ASCVD risk (Muntner, Safford, Cushman, & Howard, 2014b). Cook & Ridker, (2014) responded to Muntner et al. (2014b) indicating that these mentioned factors were not relevant for all the five cohorts and for those relevant, the effect had not been considerable to explain the total overestimation of this approach. However, they mentioned a few designs and methodological related reasons, which may have led to overestimating the risk in the five large cohorts. Canadian researchers have evaluated the risk of CVD using the pooled cohort method (Goff et al., 2014) and have compared it to the 2012 CCSG recommended risk assessment too. Their results indicated a similar prevalence for statin therapy statin therapy (Hennessy et al., 2015). Therefore, controversy still exists on the advantages and disadvantages of this new CVD risk approach.

2.2.1.6. The Cardiovascular Age Gap

According to the 2016 update of CCSG, a more meaningful approach in assessing individuals' CVD profile is known as the "heart age" or cardiovascular age (CVA) alongside the cardiovascular risk assessment. This approach has been mainly used to increase lipid-lowering therapy adherence at the clinic level. The idea behind CVA is that if an individual is at high risk for CVD compared with individuals of a similar age and sex, his/her cardiovascular system is aging faster. With the risk factors of CVA being similar to the adjusted FRS, this new approach does not require additional physical or laboratory measurements. Moreover, these guidelines indicate that assessing cardiovascular risk may not be as beneficial as evaluating CVA for younger aged individuals, as they may not be at considerable risk for CVD (Anderson et al., 2013). This approach has been known as an educational tool with regards to the cardiovascular status of an individual. A randomized cross-country study evaluated the association of patients' knowledge of his/her cardiovascular risk profile and reaching optimum lipid targets. These researchers concluded that significant small differences were observed regarding the improvement of the patient's lipid profile (Grover et al., 2007).

Risk assessment approaches have been developed based on study populations with specific characteristics. Therefore, calibration of these approaches should be done before using them for other populations. Although the cut-offs for risk factors are different among different ethnic groups and populations, the risk factors are relatively the same (Grover & Lowensteyn, 2011). Some of the risk assessment approaches have been validated by Canadian cohort studies, including the Framingham model and the SCORE model (Dasgupta et al., 2014; Grover & Lowensteyn, 2011). Thus, these calibrated methods and the most recent ACC/AHA risk assessment tool can be used to determine the association between CVD risk and lifestyle factors among Canadians.

2.3. Dietary Intake

2.3.1. Food and Nutrient Recommendations

Dietary recommendations and guidelines have been established for public health in most countries around the world. These recommendations and guidelines have been formed based on the outcome of the WHO and Food and Agriculture Organization's review of recent studies (WHO, 2014; Zlotkin, 1996). As well, many countries have adjusted dietary guidelines and recommendations to their specific populations. North American countries rely on nutritional guidance known as the Dietary Reference Intakes (Murphy, 2008). Specifically, in Canada, food recommendations offering nutritional information and recommendations for daily food intake have been offered to Canadians through Canada's Food Guide (Health Canada, 2007a). In this section, the focus will be on Canadian guidelines and recommendations regarding food/food groups.

A tool for food choices, food groups and overall eating patterns for Canadians is Canada's Food Guide. The aim of the Food Guide is to gain overall nutritional health while decreasing the risk of nutrition-related chronic conditions. This purpose is achieved through guidance in choosing foods rather than the introduction of a specific dietary pattern (Katamay et al., 2007). Since the 1940s, different versions of the Food Guide with different names and somewhat different content have been presented to Canadians. The first official food recommendations were proposed in 1942 as Canada's Official Food Rules. The Food Rules were then modified and revised until the establishment of the Food Guide in 1992. The latter was considerably modified compared to Guides presented before 1992 and was named as the "Canada's Food Guide to Healthy Eating" (Health Canada, 2007b). The food groupings were made on the basis of their commodities, agriculture, traditional use and consumers' perceptions of the food. A special group named the "other foods" for foods that were not classified in the four main food groups was established and added to the Food Guide (Health Canada, 2007c). The five groups are Grain Products; Vegetables And Fruit; Milk Products; Meat And Alternatives; and "Other Foods". In the 1992 Canada Food Guide, a total diet approach based on energy needs of different ages, genders, body sizes, physical activity levels and specific conditions, such as pregnancy and lactation, were considered.

The last version of the Food Guide was published under the title, "Eating Well with Canada's Food Guide" in 2007 (Health Canada, 2007a; Katamay et al., 2007). This revision of the Food Guide was started in 2002 and aimed to maintain the guide's strengths and improve its weaknesses (Health Canada, 2007b). The strengths were mainly its application and use among the population and its accordance with the literature on the diet-disease relationship. Weaknesses included unclear terms such as "moderate" and the "other food" group and the omission of multicultural foods. The 2007 version was based on the Dietary Reference Intakes reports of the Institute of Medicine for 16 age-sex groups, studies regarding food and chronic disease and also the stakeholders' feedback (Health Canada, 2007a). It contains different sections including: recommended number of Food Guide servings per day for 12 age-sex groups, the description of food servings, advice for making better food choices, advice for different ages and stages, recommendations for how to count servings in a meal and eat well and be active advice (Health Canada, 2007a). The 2007 Food Guide presented an eating pattern while meeting the aforementioned aims of the Food Guide in addition to meeting specific age-sex related nutrient needs (Katamay et al., 2007). However, currently, researchers have demonstrated the need for updating the 2007 Food Guide (Jessri & L'Abbe, 2015).

These dietary guidelines provide criteria for evaluating intake from different food groups. In the next section evaluation of the Canadians' dietary status based on these guidelines is discussed.

2.3.2. Dietary Status of Canadians

Food consumption and dietary patterns of Canadians have changed over the years. In this section, the dietary status of Canadians from their food group intake and prevalent dietary patterns, as two main dietary assessment approaches, among them are discussed. Several national surveys with the collection of data on nutrition have been completed since the 1970s (Sabry, Campbell, Campbell, and Forbes, 1974). The first national nutrition survey, known as "Nutrition Canada", was conducted from 1970 to 1972. The aim of this survey was to collect nutritional data to understand the nutritional status of Canadians. In this survey a 24-hour dietary recall was used to collect nutritional data. The results of this survey indicated that Canadians had certain nutrient deficiencies. Iron deficiency was noted not only in pregnant women and infants but also in children and men. As well, results revealed low intake levels of protein in pregnant women. They also found that many Canadian infants, children, adolescents, and pregnant women had inadequate milk intake, which contributed to a shortage of vitamin D and calcium in their diet. Vitamin C, A, thiamin and folate deficiencies were also observed in Canadians in the early 1970s

(Sabry, Campbell, Campbell, and Forbes, 1974).

The CCHS is a cross-sectional national representative survey in Canada. A nutrition component was added to one survey, in 2004; thus Cycle 2.2 was a national food consumption survey for the first time since the Nutrition Canada survey conducted in the 1970s (Health Canada, 2012). Through this survey, data regarding time, quantity, and sources of food were collected. A repeated 24-hour recall dietary assessment was used to collect dietary data from a subsample of this survey study population. The results of this survey showed that the energy consumption of Canadians had remained stable since the early 1970s compared to 2004; however, it had declined amongst males in the age range of 12 to 65 years (Garriguet, 2006). Moreover, while in the 1970-1972 survey, Canadians obtained 40% of their energy from fat, in 2004, this figure had declined to just over 30%, accordant to the Acceptable Macronutrient Distribution Range's (AMDR) recommendations. Fat intake in 2004 was mainly from meat and "other food" groups. Based on this survey data and compared to the 1992 Food Guide recommendations, more than half of Canadians were not consuming the minimum recommended servings of fruit and vegetables (Garriguet, 2006). This finding concurred with those from a study based on CCHS 2.1 survey data, which revealed that more than 50% of the elderly did not consume the daily recommended amount of fruit and vegetables (Riediger & Moghadasian, 2008). Furthermore, according to the results of a study based on CCHS 3.1, the fruit and vegetables intake of 77% of adult Canadians was less than five servings per day (Dehghan, Akhtar-Danesh & Merchant, 2011). According to the CCHS 2.1 survey data, almost 60% of adolescents had a maximum of five servings per day of fruit and vegetables (Riediger, Shooshtari & Moghadasian, 2007). The latter two studies also indicated that socio-demographic and lifestyle factors impact the consumption rate of fruit and vegetables among Canadians. A Food Frequency Questionnaire (FFQ) was used in all cycles of CCHS to collect fruit and vegetable intake data (Dehghan et al., 2011; Riediger et al., 2007).

The CCHS 2.2 survey data showed non-compliance to the recommended intake of Meat and Alternatives, Milk And Alternatives, Grain Products and "Other Food" products among Canadians. Regarding the intake of milk, more than 30%, 60% and 80% of children, adolescents and elderly, in Canada, respectively, failed to consume the minimum recommended amount (Garriguet, 2006). Moreover, more than 66% of this population had a maximum of two servings per day from the Milk and Alternatives group (Garriguet, 2008). Regarding meat product consumption, about 25% of males aged 14 to 70 years had more than the recommended intake of Meat and Alternatives, while 18% and 15% of females aged 9 to 18 years and 71 and older, respectively, had lower than the recommended intake of Meat and Alternatives. The number of Canadians who consumed fewer than the recommended Grain Products increased with age. At 71 years and older, 43% of males and 66% of females consumed less than the recommended intake of Grain Products. According to CCHS 2.2, around 22% of daily energy would be obtained from the "Other Food" category, which included high sugar foods such as jam; oil and fats such as butter; high fat and salt such as potato chips; beverages such as tea and alcohol; and herbs and condiments. Overall, while a large number of the population was out of the range for AMDRs, on average, the 2004 diet of Canadians followed 2002 AMDR recommendation report from the Institute of Medicine (Garriguet, 2006).

Data from CCHS Cycle 2.2 revealed Canadians consumed 110 grams of sugar per day and far more than the Institute of Medicine's recommended sodium level (Garriguet, 2007; Langlois & Garriguet, 2011). Sugar contributed to 21% of people's daily energy intake. This figure was 17% for the diabetic population. Moreover, more than 35% of the sugar intake was from the "other food" group, followed by the Vegetables and Fruit group (Langlois & Garriguet, 2011). The CCHS 2004 data showed that Canadians between the ages of 19 and 70 years had consumed more than the Institute of Medicine's recommendations for sodium intake (Garriguet, 2007).

The beverage consumption of Canadians was evaluated based on the CCHS Cycle 2.2 survey data, and results revealed that water, coffee, milk, and soft drinks were the most frequently consumed beverages. Beverage intake decreased by age and men had a higher intake (Garriguet, 2008). Twenty percent of Canadians aged 31 to 70 years exceeded the caffeine intake recommended in Health Canada's guidelines for caffeine consumption. Diet soft drinks were consumed by only a small percentage of adults, with 10% of adults aged 31 to 70 years consuming the highest amount. More than 20% of adult males and eight percent of adult females aged 19 to 70 years consumed more than two alcoholic drinks per day (Garriguet, 2008). These results on alcohol consumption concur with two other studies based on the same survey data aimed at determining beverage consumption among Canadians. The sugar-sweetened beverages were one of the predominant beverages in the diets of children, adolescents, and adults, especially for women (Danyliw, Vatanparast, Nikpartow, & Whiting, 2011; Nikpartow et al., 2012). About 33% of Canadian adults consumed fruit juice. Even counting fruit juice and vegetable juice as servings for the Vegetables and Fruit group, beverage consumption contributed to less than one serving of the Vegetables and Fruit group (Garriguet, 2008). Results of a study assessing Canadians overall diet quality in 2004 showed that the frequency of fruit and vegetable consumption had a direct relationship with diet quality (Garriguet, 2009).

Based on CCHS fruit and vegetables FFQ data, in 2009, only 46% of Canadians consumed more than five fruit and vegetable servings per day. In 2011 and 2012, around 41% of Canadians aged over 12 years reported daily consumption of five or more vegetable servings. The trends from 2001 to 2012 showed an overall higher percentage of women consuming five or more servings of vegetables per day compared to men (Statistics Canada, 2013b). Limited information is available on current Canadians nutrition intake. Thus more research is required based on data provided by Statistics Canada.

2.3.2.1. Diet Quality of Canadians

Overall diet was investigated in a few studies determining the diet quality, nutritional risk, and dietary patterns among Canadians (Garriguet, 2009; Langsetmo et al., 2010; Ramage-Morin, & Garriguet, 2013). Researchers used the HEI scoring method to assess Canadians overall diet quality. This method was used in accordance with the recommendations in Canada's Food Guide. The higher the score, the better the diet quality according to the HEI scoring method (details provided in Section 2.3.4.1.2). Canadians over the age of two years had an index score of 58.8 out of 100, with women having higher scores than men in all age categories. This score indicates that the Canadian diet "needs improvement" (Garriguet, 2009, p.4).

The CCHS-Healthy Aging 2008/2009 survey among Canadians over the age of 45 years aimed to determine nutritional risk in order to assess the risk of malnutrition. Researchers of this study used data from the 2008/2009 Canadian Community Health Survey-Healthy Aging. The nutritional risk assessment was based on weight change, nutrition intake and dietary habits (Ramage-Morin, & Garriguet, 2013). The results of this study revealed that over a third of Canadians over the age of 65 years were at "nutritional risk". "Nutritional risk is the risk of poor nutritional status, which lies on a continuum between "nutritional health" and "malnutrition" "(Ramage-Morin, & Garriguet, 2013, p3). In the Canadian Multicenter Osteoporosis Study, a longitudinal cohort, two definite dietary patterns were identified among Canadians: the "Nutrient Dense" and the "Energy Dense." The former pattern was associated with high intakes of fruit, vegetable, and whole grain, while the latter pattern was associated with a high consumption of soft drinks, potato chips, french fries and some processed meats such as hot dogs, hamburgers, bacon and sausage and also some types of desserts such as chocolate, ice-cream, and doughnuts (Langsetmo et al., 2010).

2.3.3. Assessing the Impact of Diet on Disease/Health Outcomes

Researchers have been investigating the association between diet and disease for more than two centuries. In 1753, the observation of the impact of fruit and vegetables intake on diseases led Lind to conduct the first recorded controlled clinical trial. The findings of his study eventually led to an understanding of the relationship between diet (what we now know to be vitamin C deficiency) and disease (i.e., scurvy) (Willett, 2012). Since then, many non-communicable epidemic diseases have been found to be the result of deficiencies in the diet. Diet-disease investigations have been conducted and continued via different observational and interventional study designs (Willett, 2012). There are different epidemiological study designs depending on the resources available and the nature of exposure and outcome. Study designs in the order of evidence strength are as follows: case report/series, cross-sectional, case-control, cohort, and RCTs giving the strongest proof (Willett, 2012).

In nutritional epidemiology, nutritional assessment is one important part of diet-disease relationship investigations. Nutritional assessment aims at understanding the evidence from dietary assessments and biomedical, anthropometric and clinical evaluations (Gibson, 2005). An optimal nutritional assessment approach is to use a combination of these approaches (Thompson & Subar, 2001). Depending on the available dietary information, diet can be assessed in terms of chemical composition (such as nutrients), food, food groups and dietary patterns (Willett, 2012). Dietary assessment includes a variety of traditional and modern methods of collecting dietary information, such as dietary records, 24-hour dietary recall, FFQ, brief dietary assessment instruments, diet history, blended instruments and, more recently mobile dietary devices. Each dietary assessment method is relevant for a certain aim. For example, FFQ is widely used in epidemiological studies investigating diet-disease relationships where usual intake is needed at the individual level (Thompson & Subar, 2001).

Evaluating a population's dietary pattern has been of interest to epidemiologists for many years. Food is composed of interacting, inter-correlated and synergistic nutrients, which may be confounders to each other's effects (Bountziouka, Tzavelas, Polychronopoulos, Constantinidis,

& Panagiotakos, 2011). Therefore, if a single nutrient is studied, its effect may be too small to detect (Moeller et al., 2007). Moreover, if a combination of several nutrients is studied the chances of confounding effects, collinearity, and multi-collinearity, would eventually elevate the uncertainty of statistical results (Moeller et al., 2007; Panagiotakos, 2008). Hence, identifying the influence of each nutrient independently is challenging (Hu, 2002). Because human beings tend to consume a variety of foods and nutrients at a single meal, evaluating general dietary patterns is thus more practical than examining single nutrients. This explains why many researchers assess dietary patterns in diet-disease relationship studies. The aim of evaluating dietary patterns is to understand the population's overall diet, adherence to guidelines, overall diet impact on health, leading to the eventual implementation of health-related interventional approaches (Hu, 2002). The methodological approaches used to determine dietary patterns among a population are discussed in the next section.

2.3.3.1. Dietary Patterns Approach

There are different methods to extract dietary patterns among the population. The first method is the a posteriori method, which is a data-driven method. The second method is the a priori method that is based on prior knowledge (Hoffmann, Schulze, Schienkiewitz, Nöthlings & Boeing, 2004). There are also analytical methods that are hybrids of the two aforementioned methods (Hoffmann et al., 2004) (Table 2.4). These methods will be discussed next.

A posteriori analytical approach is based on data derived from observational studies. In this method, a large set of variables is reduced to a smaller number of variables based on the correlation between the input variables (Moeller et al., 2007). This approach explains the inter-correlation of food or food groups, and it is defined by multivariate statistical approaches (Panagiotakos, 2008). Different methods exist such as exploratory factor analysis, confirmatory factor analysis (CFA) and cluster analysis (Moeller et al., 2007).

In this method, the dietary intake variables are combined into a fewer number of interrelated variables. Several studies have used this method to determine dietary patterns across different populations. In this method, the usual intake data of food items are grouped based on culinary or the dietary content. The common factor analysis and principle component analysis (PCA) are the two known methods for the exploratory factor analysis approach.

In PCA, the principal components are obtained by correlating input variables with the aim of deriving uncorrelated components. The principal components are linearly combined observed values that explain the variance in the food intake data (Moeller et al., 2007). Components are retained based on an eigenvalue of above 1 (Kaiser criterion) or by other methods such as the scree plot. As well, factors are rotated to be more interpretable, and an orthogonal rotation is commonly used (Kant, 2004; Moeller et al., 2007). Individuals are given a score for each factor, equal to the sum of the standardized input variables that are weighted by their factor loadings (Moeller et al., 2007). This method is mainly used to obtain the dietary pattern of a population regardless of the health outcome. Moreover, the dietary patterns are uncorrelated, thus can be used together in linear regression models as independent variables.

Another data-driven method, the common factor analysis, observed variables are assumed to be the linear combinations of the latent variables (factors). The factor scores obtained are estimates of the actual unobservable factor. Despite the conceptual difference between the two methods of PCA and common factor analysis, similar results are obtained (Michels & Schulze, 2005). These two methods have shown to be reproducible over time and using different dietary assessment methods (Michels & Schulze, 2005). There are some limitations regarding these two exploratory factor analysis methods including subjectivity, correlated measurement error and patterns derived not being associated with the disease (Michels & Schulze, 2005).

The “Prudent,” “Healthy” and “Western” patterns or more specific patterns such as “Sweets” and “Alcoholic” dietary patterns were observed in many studies using these methods (Tucker, 2010). The “Prudent” and ”Healthy” dietary patterns were characterized by high intakes from fruits, vegetables, whole grains, fish and low-fat dairy. The “Western” pattern was loaded by high intake from red/processed meat, fried potatoes, sweet and salty snack and soft drinks (Tucker, 2010).

Cluster analysis is a method in which individuals with similar dietary characteristics are aggregated into mutually exclusive and non-overlapping groups or clusters (Hu, 2002). In using this method, the usual intake data of food items are grouped based on culinary or the dietary content. They are then standardized due to the sensitivity of this method to extreme values. The distance of the observations to the seeds is chosen to cluster the individuals. Then the midpoints (observation) of the clusters are assigned as the seed, and this process continues until the most optimal clustering is obtained (i.e., the distance between observations in a cluster are less than the distance between clusters) (Mitchels & Schulze, 2005). The K-means and Wards methods are used for clustering. Further, in choosing the relevant clusters methods such as the scree plot can be applied (Moeller, 2007). After clusters are derived, a comparison between the diets of clusters would guide through naming the clusters (Hu, 2002). Different studies have obtained similar dietary patterns commonly known as “Sweets,” “Alcoholic” or “Traditional” patterns (Moeller et al., 2007).

Factor analysis and cluster analysis address the research question in different ways. Cluster analysis explores if there are different groups in the population in terms of their diet, whereas factor analysis identifies different patterns of eating (Moeller et al., 2007). However, both methods are not designed to extract dietary patterns that predict disease (Moeller et al., 2007). Should the purpose of the study be identifying subgroup dietary pattern analysis, cluster analysis is preferred over PCA or factor analysis. However, the drawback is the reduced power. Thus the sample size should be large (Tucker, 2010).

CFA is a structural equation modeling method, which derives latent variables (dietary patterns) that are associated with observed variables (dietary intake data) (Varraso et al., 2012). The specifications of the model such as the number of dietary patterns and the food groups loading on the patterns are determined based on a priori knowledge of the data or from the literature. In this method, based on priori knowledge, a number of different models are built using the number of latent variables and correlation status. The global fits, interpretability, and relevance of the model to the literature are considered to retain the best model. The global fits of the models are measured using different methods such as the goodness of fit method. Other than a few studies (Varraso et al., 2012; Bédard et al., 2015), researchers have rarely used the CFA in the field of nutritional epidemiology. In most studies, this method was used to validate exploratory methods or to compare stability between studies (Bédard et al., 2015). Recently, researchers have used the CFA method as a one-step independent method to derive patterns in parallel with PCA (Bédard et al., 2015). These researchers have demonstrated that despite the comparability of the two methods, CFA derived patterns have higher stability and less subjectivity compared to PCA-derived patterns (Bédard et al., 2015).

The other main analytical approach to identifying dietary patterns is the a priori analytical method. This approach is based on using existing food/food group knowledge, guidelines and recommendations (Davenport, Roderick, Elliott, Victor & Geissler, 1995; Garriguet, 2009). There are four main scoring classification methods, which evaluate the population’s adherence to certain recommendations or healthy diets (Panagiotakos, 2008). These methods include the following: 1) the nutrient density scoring method, which evaluates the dietary quality of food rather than the total dietary pattern; 2) diversity scores, which determine the variety of food and/or food groups; 3) food group patterning scores, which are based on the main food groups; and 4) the index-based summary scores, which are widely used in nutritional epidemiology and are based on elucidating different dietary guidelines or recommendations (Moeller et al., 2007). Besides indices based on recommendations, diet models with well-known beneficial impacts on health such as the “Mediterranean” diet (Panagiotakos, 2008), may be used to compare with what is observed in data (Bountziouka et al., 2011). The overall aim is to compare and classify the population into categories based on the similarity to the previously proven “healthy” models or indices (Panagiotakos, 2008).

Score-based methods used to define dietary patterns give results indicating the characteristics of the total diet. Moreover, the analytical procedures applied are reproducible and convenient (Moeller et al., 2007). However, the limitations of this method must be considered, including the following: 1) since the guidelines used may be subjective or specific for certain diseases, it is important to consider research questions and the type of data available before choosing the methodology; 2) the amounts of certain food or food groups in the extreme must be considered; 3) dichotomizing food categories (e.g. fruit vs. no-fruit) may lead to the underestimation of foods consumed; 4) because diet is multifactorial, the underlying components of the index or model should be related to one another; and 5) the association of each component with the disease is not well understood (Moeller et al., 2007). Recently, the HEI, which is an overall diet quality index, has been used to evaluate the diet of Canadians (Garriguet, 2009). The Healthy Eating Index (HEI) index is explained in the following section.

The HEI is a diet quality index, which was released in 1995 by the U.S. Department of Agriculture Center for Nutrition Policy and Promotion (Guenther, Reedy, Krebs-Smith, Reeve & Basiotis, 2007). This index was developed based on the Food Guide Pyramid and the Dietary Guidelines for Americans (DGA). The purpose was to monitor Americans’ diet and to measure their compliance with the DGA (Garriguet, 2009; Guenther et al., 2007). The HEI includes the following ten components: total fruit, total vegetables, total grains, milk, meat, sodium, saturated fat, total fat, cholesterol and diet variety. The maximum score for HEI is 100 points (Guenther et al., 2007). Three total score ranges were defined for score ranges of less than 50, 50 to 80 and higher than 80 points, as “poor diet” quality, diet quality “needs improvement” and “good” diet quality, respectively (Garriguet, 2009). Researchers have validated this index by observing correlations between the index scores and nutrient intakes (Kennedy, Ohls, Carlson and Fleming, 1995) and biological measures (Hann, Rock, King and Drewnowski, 2001).

In 2005, a revised version of this index called the HEI-2005 was developed based on the revised DGA. The modifications in this version of the index were concerning whole grains, various types of vegetables, specific types of fat, and also a component was added, which included the “discretionary calories” idea. The HEI-2005 was evaluated and confirmed in terms of content and construct validity and internal consistency (Guenther et al., 2007). There are six main limitations of HEI-2005: 1) it does not cover young children; 2) it is unsuitable for ethnic groups with considerable differences in their diet compared to the mainstream population; 3) scores are density-based, which may be misleading when under/over reporting of intake is an issue in the population; 4) most components have similar weights (10 points); 5) twenty points have been assigned to the fat component of the diet, which may be unnecessarily high; and 6) since this index is based on recommendations, it should include other components to cover adherence to all recommendations (Guenther et al., 2007; Woodruff, & Hanning, 2010).

A few researchers have modified and used the original HEI and HEI-2005 to evaluate the diet quality of different populations (Table 2.3). Glanville and McIntyre (2006) have modified the original HEI to evaluate the diet of Atlantic single mothers and their children (ages 1 to 14). They called this Canadian modified index the HEI-C. This modification was based on the recommended intakes of Canada’s Food Guide to Healthy Eating and Nutrition Recommendations for Canadians. Moreover, in this revised index the variety component score was assigned by adding up the serving intakes from all food groups. As well, the “other food” group intake was considered as a component and substituted the sodium component in the original HEI. The reason for excluding the sodium component was that it did not capture the table salt intake (Glanville and McIntyre, 2006). These researchers concluded that younger children have a better diet quality status compared to their mothers and older children.

Two other studies have developed an HEI based index appropriate for the Canadian population. In 2010, other Canadian researchers updated the HEI-C based on the Eating Well with Canada’s Food Guide and the HEI-2005 to evaluate a small sample of adolescent’s diet quality (Woodruff, & Hanning, 2010). In this newly revised index called the HEIC-2009, scores are allocated based on absolute serving intake versus intake per total energy. Moreover, the intakes from vegetables/fruit and grain components have been assigned according to the Eating Well with Canada's Food Guide (Woodruff, & Hanning, 2010). These researchers found that the diet quality score was higher using the HEIC-2009 compared to when HEI-C was applied; however, both scores belonged to the "diet [that] needs improvement" category. These modified indices including HEI-C and HEIC-2009, used among the Canadian population, should be validated across different anthropometrics, and clinical and biological measures (Woodruff, & Hanning, 2010). The HEI-2005 was adapted by Garriguet (2009) to evaluate the diet quality among the general Canadian population. This Canadian adapted index was developed based on the Eating Well with Canada's Food Guide. The data from CCHS 2.2 was used to assess diet among Canadians by the Canadian adaptation of HEI-2005 (Garriguet, 2009). Results of this study indicate that Canadian's diet quality needs improvement (Garriguet, 2009). The latter two Canadian indices have similarly considered absolute intakes rather than intakes relative to energy in their scoring of the components. However, these two indices have different components compared to one another (Table 2.3) (Garriguet, 2009; Woodruff, & Hanning, 2010).

Table 2. 3. Canadian studies which developed an index based on the Healthy Eating Index.

Study Description	Population	Revision Done on	Modification of HEI Based on	Name of the Revised HEI Developed	Considerations
Glanville & McIntyre, 2006	Atlantic single mothers and their children	HEI-Original	1. Canada's Food Guide to Healthy Eating 2. Nutrition Recommendations for Canadians	HEI-C	- Included children aged three and younger. - Nine components - The variety component based on the serving consumption from food groups. -The "other food" group intake was substituted for the sodium component
Garriguet, 2009	Canadian general population	HEI-2005	Eating Well with Canada's Food Guide	Canadian adaptation of HEI	-Serving for age-sex instead of relevance to energy - Eleven components -Components modified
Woodruff, & Hanning, 2010	Small sample of Canadian adolescents	HEI-C	1. Eating Well with Canada's Food Guide 2. HEI-2005	HEIC-2009	-Revision of 50 % of the HEI-C scores -Nine components -Grains and vegetables and fruits component -Absolute scores, no longer relative to energy

HEI, Healthy Eating Index

Hybrid Pattern Analysis Methods

There are a few other dietary analysis methods including the reduced rank regression (RRR) and the partial least square regression (PLS) method that are hybrids of the aforementioned methods (Hoffmann et al., 2004). Their methodology includes both the mathematical technical procedure of PCA for deriving the factors and index method to construct the intermediate variables (Hoffmann et al., 2004). The RRR method is a statistical approach that linear functions of food/food group are obtained based on maximizing the explained variation in intermediate variables (nutrients or risk factors that have a main role in the etiology of the outcome) (Hoffmann et al., 2004). In the PLS method factors are extracted and explain both the variation in food items and intermediate response variables. The technical procedure of extracting the factors in both RRR and PLS are similar to PCA. In the RRR method, the correlation coefficient of the response correlation matrix is used, while in PLS the predictor-response correlation matrix is used (Hoffmann et al., 2004). The response scores are then projected on to the predictors to obtain factor scores. In the last step, the extracted factors, which are uncorrelated in these two methods, can be tested in terms of having an association with the outcome (Hoffmann al., 2004). Low reproducibility and requiring a priori knowledge about the outcome are counted as limitations of these methods. However, when specific intermediate variables (ex. omega-3 fatty acids and dyslipidemia) related to the disease are selected, then a stronger association was observed with the outcome that is an advantage over other analytical methods (Hu, 2002). Also, in data-driven approaches when a factor is found to have an association with disease, the reason behind it is not as apparent as it should be since it is at the level of food groups (Hoffmann et al., 2004).

In conclusion, all dietary patterns have advantages and disadvantages (Table 2.4), indicating that no one method is the best method of all. Moreover, researchers have used different methods to investigate a similar topic such as the association between dietary patterns and MetS (Chapter 3).

Table 2. 4. The most common dietary pattern approaches used in nutritional epidemiology and their advantages and disadvantages.

	A priori methods	**A posteriori**		**Hybrid methods- Reduced ranked regression**
		Principle component analysis	**Cluster analysis**	
Approach	Index with multiple components developed to assess the adherence of the population to dietary recommendations or a specific diet (ex. Mediterranean diet).	Dietary patterns of the population are extracted using available data by a dimension reduction method.	Distinctive groups are determined based on the dietary pattern by a dimension reduction method.	Intermediate-based dietary patterns are evaluated in terms of their association with health outcome (intermediate variables are chosen that based on the literature related to the health outcome)
Advantage	-Determines the adherence to guidelines and recommendations. -Reproducible, simple computation, comparable and interpretable results. -Ranked scores could be used in linear regression models.	-Factors are uncorrelated, thus, could be used in the model simultaneously. -Can be used with limited prior knowledge regarding the health outcome.	-Mutually exclusive clusters. -For planning dietary interventions.	-Factors are uncorrelated. -Factors could be used in the model simultaneously. -Disease-specific intermediate factor using a priori knowledge are used. -In the case of available a priori knowledge, gives interpretable results -The numbers of factors are not more than a number of intermediate variables. -With strong intermediate predictors, dietary patterns show to have an association with the outcome.
Disadvantage	-Does not consider correlation and synergic effect of components on one another. -Midrange total scores are not much interpretable compared to extremes. -Scores do not give much information on the exact diet.	-May not observe an association between patterns and health outcome. -Subjectivity in choosing a number of factors retained and the factor loadings. -Interpretation of the association between the dietary	-Sensitive to extreme outliers. -Requires large samples. -Subjectivity in choosing clusters number and names -Less reproducibility due to population-driven scores.	-Subjectivity in choosing the intermediate factors. -Since there are measurement errors in the dietary assessment methods, thus it affects the representativeness of the nutrient intermediate variable. -Non-reproducibility of the factor scores coefficients.

- Indices are developed based on recommendations that may not be related to specific diseases. - Dichotomizing or ranging scores would lose information, especially for extreme values. - Each component score should be interpreted independently otherwise total score gives limited information -The ethnic dietary patterns are masked.	pattern and health outcome is difficult. -Assigning the dietary pattern with the highest score to individuals can result in losing information. -Scores don't give much information on the exact diet. -Food grouping may obscure ethnic dietary patterns. -Less reproducibility due to population-driven scores.	-Interpretation of the association between the dietary pattern and health outcome is difficult.	-Patterns are not the actual dietary patterns among populations. -Since patterns are explaining the maximum variance of the intermediate factors, which have been chosen because of their association with the outcome, thus the patterns should have an association with outcome anyway.

* Hoffmann et al., 2004; Moeller et al., 2007; Tucker, 2010; Panagiotakos, 2008

2.4. Complex Nutrition and Health Surveys

It is central to government public health efforts to monitor and improve the nutritional status of citizens. Statistics are essential in understanding the health and nutritional surveillance of a nation. National surveys, including health interview surveys and health examination surveys or a combination of the two, have been used to collect data in developed and developing countries. In health examination surveys, a combination of examinations may be conducted, including anthropometrics, physical examinations, individual medical interviews and a variety of laboratory tests (Fisher, Pappas & Limb, 1996). An important survey including both health examination surveys and health interview surveys conducted in the U.S. was the National Health and Nutrition Examination Surveys (NHANES), which began in the 1960s (Centers for Disease Control and Prevention, 2014). The CCHS and CHMS are two Canadian national health surveys.

Initially, each NHANES was conducted sporadically, using Roman numerals to indicate new surveys (e.g., I, II and III). They have been conducted by the Center for Disease Control and Prevention of the National Center for Health Statistics in the U.S. (Center for Disease Control and Prevention, 2014; Fisher et al., 1996). Since 1999, this survey has collected data from about 5000 different adults and children on a yearly basis and has focused on different groups or healthy subjects (Center for Disease Control and Prevention, 2014). Data from the 2013-2014 NHANES cycle is the most recent release (Center for Disease Control and Prevention, 2016). This survey has always included a dietary assessment component, now known as "What We Eat in America." Through NHANES, interviews, physical and laboratory examinations are done, and the health and nutritional status of the U.S. population could be accessible to researchers, government, and the private sector. The nutrition component has been mainly based on 24-hour dietary recalls (Wright et al., 2007).

The CCHS is a cross-sectional national and provincial representative survey in Canada that has been conducted since 2000. This survey, conducted by the Canadian Institute for Health Information, Statistics Canada, the Public Health Agency of Canada and Health Canada, collects information on health status, the health care system and health determinants from Canadians aged zero and above. Before 2007, this survey was conducted biannually; however, since 2007, the data collection has been annual with a two-year period of time for each cycle. Approximately 65,000 participants have been included each year in the annual component or in the focused survey since 2007 (Statistics Canada, 2013c). As mentioned in section 2.3.2., a nutrition component was added to one survey, in 2004 Cycle 2.2 for the first time since the Nutrition Canada survey conducted in the 1970s. The CCHS 2.2 survey evaluated the diet of Canadians through 24-hour dietary recalls (Health Canada, 2012). Another cross-sectional nationally representative health survey is the CHMS (Statistics Canada, 2011). The characteristics of this survey with a focus on Cycles 1 and 2 are further described in the next section.

2.4.1. Canadian Health Measures Survey

The CHMS is a Canadian cross-sectional nationally representative health survey that runs in bi-yearly cycles. This survey is conducted by Statistics Canada in collaboration with Health Canada and the Public Health Agency of Canada. The main objective of this survey is to fill the gaps in national health information. The focus of CHMS is on diseases, health, social/lifestyle and environmental conditions. Health Canada's Research Ethics Board has given the ethics approval of CHMS (Statistics Canada, 2011 & 2012a, b). Initially, an interview is held at the household. This interview collects demographics and thorough health information. A few days after the household interview, the participant visits a mobile examination center (MEC) for the interview and the physical and laboratory sampling process (Statistics Canada, 2011 & 2012a). The CHMS Cycles 1, 2, 3 and 4 were conducted from 2007 to 2015. These cycles included approximately 5,500 to 6500 participants (aged three to 79 years). Data from each CHMS cycle is released within different “waves”. Each wave contains the previous data included in the master file in addition to new data released. For example, Wave 2 of Cycle 1 contained Wave 1 plus the laboratory results released for the first time (Statistics Canada, 2011, 2012a, c and 2015c).

2.4.1.1. Sample Design

The CHMS national survey’s target population covers people aged 3 to 79 (ages three to five were not included in CHMS Cycle 1) living in 10 provinces. The survey covers almost 96.3% of the target population. Excluded are people living on reserve or in other Aboriginal settlements, fulltime members of the Canadian Forces, institutionalized residents and people living in remote regions and regions with low population density. In this Canadian survey 11 age-sex groups are considered as follows: male and females within the age ranges of 3 to 5 (not included in Cycle 1), 6 to 11, 12 to 19, 20 to 39, 40 to 59 and 60 to 79 years (Statistics Canada, 2011, 2012a, c and 2015c).

The sampling procedure in CHMS is based on a multistage sampling strategy, including the sampling of collection sites and dwelling sampling. In the surveys done between 2007 and 2011, using the Labor Force Survey sampling frame, 257 censuses metropolitan areas were selected based on the participants' distance to the medical MEC and the total population of the area (Statistics Canada, 2011 & 2012a). To ensure national representativeness of the sample, collection sites were stratified into the following five regions: Atlantic (Newfoundland and Labrador, Prince Edward Island, Nova Scotia, and New Brunswick); British Columbia; Ontario; the Prairies (Alberta, Manitoba and Saskatchewan); and Quebec. Finally, a total of 15 collection sites for Cycle 1 and 18 collection sites for Cycle 2 were allocated based on the population proportion of the five regions. Seasonality and temporal effect due to operational and logistic limitations were considered (Statistics Canada, 2011 & 2012a). The second step of the sampling procedure was conducted at the dwelling level, with the goal of selecting the appropriate number of participants required for the age groups. Data from the "2006 Census" and "Address Register" were used to obtain information on the participant's age in each dwelling. The 514 (Cycle 1) and 623 (Cycle 2) dwellings were chosen, using the simple random sampling method. Through contacting the selected dwellings, related information was confirmed or revised. If the person chosen was 11 years and younger, a second person from other age strata was also chosen to attend MEC at the same time; otherwise, only one person was selected from the dwelling (Statistics Canada, 2011 & 2012a). A fasted sub-sample was selected randomly among the dwellings. Almost half the participants who visited the MEC in the morning were included in the fasted sub-sample (combined fasted subsample n=5,427 respondents; Cycle 2 n=2,634). Pregnant or diabetic respondents were not required to fast. In addition, an activity monitor and a tobacco sub-sample were included in the survey (Statistics Canada, 2011 & 2012a).

2.4.1.2. Data Collection

The first cycle of CHMS started in March 2007 and ended in February 2009 in 15 collection sites at five main sites. The second cycle of CHMS began in August of 2009 and ended in November of 2011 in 18 collection sites at five main sites (Statistics Canada, 2011 & 2012a). To conduct CHMS, three groups collaborated, including the field, MEC, and head office teams. The groups used two trailers joined together as the MEC at each site for administrative and clinical purposes. Computer-assisted interviewing was used to collect data. Medical devices were directly connected to a data capture system in the MEC to avoid data entry errors. At the end of each session, data was transferred to the Statistics Canada headquarters from each MEC server (Statistics Canada, 2011 & 2012a).

Two main questionnaires, including the household and the clinic, were used to collect information. These questionnaires were developed based on feedback from the stakeholders, other national surveys, such as the CCHS, and suggestions from focus groups and interviews (Statistics Canada, 2011 & 2012a). The dietary assessment was done through a semi-quantitative FFQ (Statistics Canada, 2011 & 2012a, b).

About seven to 14 days before the household interview, information was sent to selected people. Once the respondents had contacted MEC, an introduction was given, and the voluntary and confidentiality information explained. On the day the CHMS staff visited the household, the interview began with a short introduction. Respondents younger than 12 years were able to ask their parents or guardians for help in answering the questions. At the end of the household interview, the respondent received a package containing information on the MEC interview and the physical examination part of the survey, which would be conducted later. After the household interview, data were transferred at the MEC using the encryption software for confidentiality purposes (Statistics Canada, 2011 & 2012a).

When the respondent arrived for the MEC visit, personal data were checked and confirmed, and consent was obtained to continue the process. During the visit, measures and tests were performed. Some test analyses were done at the MEC center, while others were sent to reference laboratories. At the end of the MEC visit, some lab results were given to the participant and also follow-up letters if tests indicated that further investigation was required and upon request of the respondent (Statistics Canada, 2011 & 2012a).

To minimize non-responses for the household interviews and refusal to comply with MEC procedures, some practices were considered such as the following: addressing language barriers by having a language competency interviewer or asking one of the household members to translate for the respondent, working with youth respondents (12 to 17 years of age) and making the survey process clear for their parents, doing proxy interviews for children (six to 11 years of age) and offering flexible hours to respondents. The adjusted final national response rate was 51.7 and 55.5% for Cycle 1 and 2, respectively (Statistics Canada, 2011 & 2012a).

2.4.1.3. Differences Between CHMS Cycles 1 and 2

CHMS Cycles 1 and 2 were similar with minor modifications applied in the second cycle, including the following that are relevant to MetS:

- The fish and shellfish components were removed in Cycle 2 from the household questionnaire. This component was modified, expanded and was included in the MEC questionnaire of Cycle 2.
- Two components regarding medication use and eligibility screening for physical measures tests were added.
- Protocols for waist circumference (in Cycle 2 using both the WHO and National Health Institute protocols, while in Cycle 1, the former protocol was used) was modified.
- Participants aged three to five years were added to Cycle 2 respondents; however, not all questions were asked from participants in this age group.
- Corresponding to the measurements of the blood pressure age range in MEC, blood cholesterol, and blood pressure related questions were asked to children aged six to 11 years in Cycle 2.
- The low-density lipoprotein cholesterol was measured directly in Cycle 1, while it was derived from triglyceride, HDL-C and total cholesterol levels in Cycle 2. (Statistics Canada, 2012a, 2014)

2.4.2. Combining Survey Data

Data from large surveys are beneficial in determining the prevalence, trends, and associations among different variables of interest. However, there are issues, mainly related to the quantity of the data, which researchers may face when working with collected survey data (Roberts, Binder, 2009; Schenker & Raghunathan, 2007). These issues include coverage concerns, non-epidemic variables, and small sample size. To overcome these issues, data may be combined from independent surveys or from cycles or series of the same survey to overcome some of these issues. Combining survey data from more than one survey or cycle can result in a larger sample size and coverage, strengthening statistical analysis and reducing sampling error (Roberts, Binder, 2009; Schenker & Raghunathan, 2007).

Although an approach that combines data from different surveys is undoubtedly beneficial, the limitations of this method should be considered such as the lack of comparability (e.g. questionnaires and collection design) (Schenker & Raghunathan, 2007; Thomas & Wannell, 2009). However, fewer of these limitations are observed when surveys combined are more similar (Thomas & Wannell, 2009).

There are two main ways of combining data from different surveys: the pooled approach and the separate approach. Through the separate approach data from different surveys are analyzed, and the final estimate of each is then combined to obtain the final result. Interpreting the results of this method is convenient, but the method is cumbersome (Roberts & Binder, 2009). In the pooled approach, data are combined in the initial step, making one combined population while adjusting for weights. Statistical power is enhanced by the increase in population size. However, a disadvantage of this method is that access and expertise with micro-data files is needed (Roberts & Binder, 2009). This method has been recommended by Statistics Canada to be used in combining the CCHS series and CHMS cycles (Thomas & Wannell, 2009).

Recently, combined data from CHMS Cycles 1 & 2 have been used in research in Canada. In one study, researchers assessed the relationship between sedentary time pattern and cardiometabolic indicators using data from CHMS Cycles 1 & 2. While 7,069 participants aged 20 to 79 years were eligible, 4,935 people were included in the study with completed data. If only one cycle data had been included in the analysis, the latter number would have been almost half, contributing to lower power in the statistical analysis. The researchers concluded that the results of this large sample of Canadians showed the optimal impact of breaking sedentary time on cardiometabolic biomarkers (Carson et al., 2014). In another study, researchers combined data from similar surveys to the previous study with the aim of assessing MetS among children and adolescent Canadians. In this study, 1,228 respondent aged 10 to 18 years were included (MacPherson et al., 2016). In the latter two studies, the “Instructions for Combining Cycle 1 and Cycle 2 CHMS” provided by Statistic Canada for researchers were used (Statistics Canada, 2014). Moreover, the full weight for combined Cycle 1 & 2 data was used with a degree of freedom of 24 (11 and 13 degrees for Cycles 1 and 2, respectively).

In conclusion, the rising prevalence of MetS indicates the importance of investigating the association of modifying risk factors such as diet in preventing this health complication. MetS has multiple underlying risk factors. Thus, in investigating its (MetS) association with diet, it is important to consider the whole diet or the dietary pattern approach. In Chapter 3, using a scoping review, the association of MetS and dietary patterns has been evaluated in a global perspective.

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CHAPTER 3: Literature Review 2

Published Paper:
Hosseini Z, Whiting SJ, Vatanparast H. Current Evidence on the Association of the Metabolic Syndrome and Dietary Patterns in a Global Perspective. Nutrition Research Reviews. 2016;29(2):152-62.

3.1. Abstract

MetS is a key indicator of two main causes of death worldwide: CVD and diabetes. This study aimed to perform a review of the population-based research on the association of dietary patterns and MetS in terms of methodology and findings. For the purpose of this study, a scoping literature review was conducted using MEDLINE, EMBASE databases and hand searching in Google Scholar. 39 population-based studies were selected. Most of these studies used a factor analysis method and the a priori dietary approach, which had been initially extracted via a posterior methods such as using the Mediterranean dietary pattern. The main finding was that following the Mediterranean or similar "Healthy" pattern reduced risk of MetS while following a "Western" pattern increased risk of MetS. The methodological approach in determining the dietary pattern of a population, whether a priori or a posteriori, should be chosen based on the purpose of the research. Overall, evidence suggests a diet based on the components of the Mediterranean diet and the avoidance of the "Western" diet can aid in preventing MetS.

3.2. Introduction

Two main causes of death and morbidity in the world are CVD and diabetes. The MetS is a cluster of important risk factors related to these diseases, including central obesity, reduced HDL-C, dyslipidemia, elevated fasting plasma glucose, and hypertension. Having MetS increases the risk of developing CVD and diabetes by two and five times, respectively (Alberti etal., 2009). Genetics, physical activity, and diet are known key factors to impact the status of this syndrome. The NCEP-ATP III and the AHA have recommended diet-based plans as one principal approach to prevent metabolic disorders predisposing to the CVD (Expert Panel on Detection, 2001; Sonnenberg et al., 2005).

Diet is composed of interacting and inter-correlated nutrients, making it challenging to identify the influence of each nutrient independently (Hu, 2002). Moreover, metabolic disorders including the MetS have been shown to have an association with food and dietary patterns rather than nutrients, with a few exceptions such as vitamin D (Forouhi & Sattar, 2006; Fung et al., 2012; Martinez-Gonzalez & Martin-Calvo, 2013). Researchers have been successful in reducing the risk of MetS development when using an overall diet modification approach in interventional trials (de Lorgeril et al., 1998).Therefore, exploring dietary patterns with regards to MetS may be a beneficial way to understand the impact of diet on MetS (Hu, 2002).

Dietary patterns are determined based on two main approaches including the a posteriori and a priori methods (Panagiotakos, Pitsavos, Chrysohoou, Skoumas, & Stefanadis, 2008). In the a posteriori approach, derived data are applied in multivariate statistical approaches to explain the inter-correlation of food or food groups. This approach includes cluster analysis and factor analysis including common factor analysis and PCA (Panagiotakos et al., 2008) as well as new approaches such as reduced ranked regression and partial least squares regression (Hoffmann, Schulze, Schienkiewitz, Nöthlings, & Boeing, 2004). In the second main analytical approach, the a priori, existing food/food group knowledge, guidelines, and recommendations, and healthy known dietary patterns are used to develop indices (Davenport, Roderick, Elliott, Victor, & Geissler, 1995; Garriguet, 2009).

Researchers have evaluated the association between dietary patterns and MetS using different study designs including randomized controlled trial (RCT) and population-based studies (Kastorini et al., 2011) Kastorini et al. have conducted a meta-analysis to evaluate the association of MetS and Mediterranean diet using both population-based studies and clinical trials published up to 2010. The updated systematic review by Esposito et al. in (2013) confirms their previous results (Kastorini et al., 2011). Further, Calton et al. (2014), conducted a review on the literature from 2000-2012 including prospective studies and RCT to evaluate the beneficial dietary pattern that has a protective role on MetS status with emphasis on the contribution of these patterns in the Asia-Pacific region. They have also concluded the beneficial effects of Mediterranean diet, Nordic diet, and Dietary Adherence to Stop Hypertension diet and the need for further RCTs to investigate their effect for the future. High standard RCTs are the most valuable evidence for inferring causality. However, we chose to focus on population-based studies where subjects are consuming their usual self-selected diets for two reasons. First, this allows investigation of "real-world" populations with different characteristics (Meyskens & Szabo, 2005; Willett, 2012). Second, population-based studies help in understanding the dietary patterns that are prevalent among a population and their association with MetS. This focus would contribute to understanding the real-life dietary practices of populations upon which dietary recommendations can be structured (Satija, Yu, Willett, & Hu, 2015)

The association between MetS and dietary patterns, however, has not been recently evaluated using population-based studies. Furthermore, the methodologies to extract the dietary patterns among populations have not been categorized and compared within this context. Therefore, the objective of this research study is to perform a scoping review of the most recent evidence on the association between dietary patterns and MetS using population-based studies. A secondary aim was to identify commonly used methodological approaches for investigating dietary patterns and justifications behind them among population-based studies in developed and developing countries.

3.3. Methodology

For the purpose of this study, a scoping literature review was conducted using the framework provided by Arksey and O'Malley (Arksey & O'Malley, 2005). A Scoping review, a tool to understand the available knowledge of a field (Sanou et al., 2014) includes the following steps: identifying the studies based on the research question, selecting studies and charting the data and finally summarizing the results (Arksey & O'Malley, 2005). We conducted the review based on the following research question: what is the relationship between dietary patterns and MetS among populations comparing two common methods of dietary pattern approaches including the a priori and the data-driven approaches?

The inclusion criteria considered for this review study were: 1) published full-text articles between 2005 and 2014 (inclusive); 2) studies that investigated the association between MetS status and dietary patterns (using a priori-defined and/or data-driven analytical approaches); 3) population-based studies including cohorts and cross-sectional designed studies with a sample size of more than 300 individuals; and 4) English language journals. Exclusion criteria were: 1) studies that have used uncommon dietary pattern analytical approaches (e.g. reduced ranked regression and partial least square); 2) studies that have focused on a special migrated ethnicity to another country; and, 3) review articles.

The search was conducted using three electronic data-bases including MEDLINE, EMBASE, and hand searching in Google Scholar. As well, the bibliographies of relevant articles were evaluated. Initially, the combination of keywords/subject heading of "Metabolic Syndrome", "Metabolic Syndrome X", "Insulin Resistance Syndrome" with general terms of the topic including "diet" and "dietary pattern" or specific dietary pattern methods including the following terms: "factor analysis", "cluster analysis", "reduced rank regression", " partial-least square regression", "dietary index", "Mediterranean diet", "Healthy Eating Index", "DASH/Dietary Approaches to Stop Hypertension", "Dietary Guidelines for American Index" and "vegetarian diet" were searched. The identified studies were evaluated in terms of inclusion and exclusion criteria by three independent authors (ZH, HV& SW). In case of disagreement, discussion led to a consensus among the authors. The selection procedure was done starting from evaluating the title, abstract and full text (Figure 3.1). The search strategy and subject headings/keywords used to conduct the search in MEDLINE and EMBASE are included in Appendix A.

3.4. Results

3.4.1. Characteristics of Studies

A total of 39 studies, published from 2005 to 2014, met the inclusion criteria and were included in this review. Seven of these epidemiological studies had longitudinal (Duffey, Steffen, Van Horn, Jacobs, & Popkin, 2012; Kesse-Guyot et al., 2013; Kimokoti et al., 2012; Lutsey, Steffen, & Stevens, 2008; Pimenta et al., 2015; Rumawas, Meigs, Dwyer, McKeown, & Jacques, 2009; Shang et al., 2011) design and the remaining (n=32) had a cross-sectional design. The studies were conducted in 23 different countries including: Algeria (Thanopoulou et al., 2006), Australia (Ambrosini et al., 2010), Bulgaria (Thanopoulou et al., 2006), China (He et al., 2013), Egypt (Thanopoulou et al., 2006), Finland (Kouki et al., 2012), France (Kesse-Guyot et al., 2013), Germany (n=2) (Barbaresko et al., 2014; Heidemann, Scheidt-Nave, Richter, & Mensink, 2011), Greece (n=4) (Gouveri et al., 2011; Panagiotakos, Pitsavos, Skoumas, & Stefanadis, 2007; Thanopoulou et al., 2006; Tzima et al., 2009), Guatemala (Gregory, McCullough, Ramirez-Zea, & Stein, 2009), Iran (n=3) (Esmaillzadeh et al., 2007; Hosseini-Esfahani, Jessri, Mirmiran, Bastan, & Azizi, 2010; P Saneei, Salehi-Abargouei, Esmaillzadeh, & Azadbakht, 2014), Italy (n=3) (Buscemi et al., 2014; Leite &

Nicolosi, 2009; Thanopoulou et al., 2006), Japan (Akter, Nanri, Pham, Kurotani, & Mizoue, 2013), Korea (n=4) (Cho, Kim, Cho, & Shin, 2011; Hong et al., 2012; Kim & Jo, 2011; Song & Joung, 2012), Lebanon (Naja et al., 2013), Mexico (Denova-Gutierrez et al., 2010), Portugal (Fonseca, Gaio, Lopes, & Santos, 2012), Samao (DiBello et al., 2009), Serbia-Montengro (Thanopoulou et al., 2006), Spain (Alvarez Leon, Henriquez, & Serra-Majem, 2006), Sweden (Berg et al., 2008), Taiwan (Shang et al., 2011) and the United States (n=10) (Deshmukh-Taskar et al., 2009; Duffey et al., 2012; Fogli-Cawley et al., 2007; Kimokoti et al., 2012; Lutsey et al., 2008; Pan & Pratt, 2008; Rizzo, Sabate, Jaceldo-Siegl, & Fraser, 2011; Rumawas et al., 2009; Sonnenberg et al., 2005; Yang, Farioli, Korre, & Kales, 2014). The studies enrolled from 323 (Naja et al., 2013) to over 93,209 (Shang et al., 2011) participants.

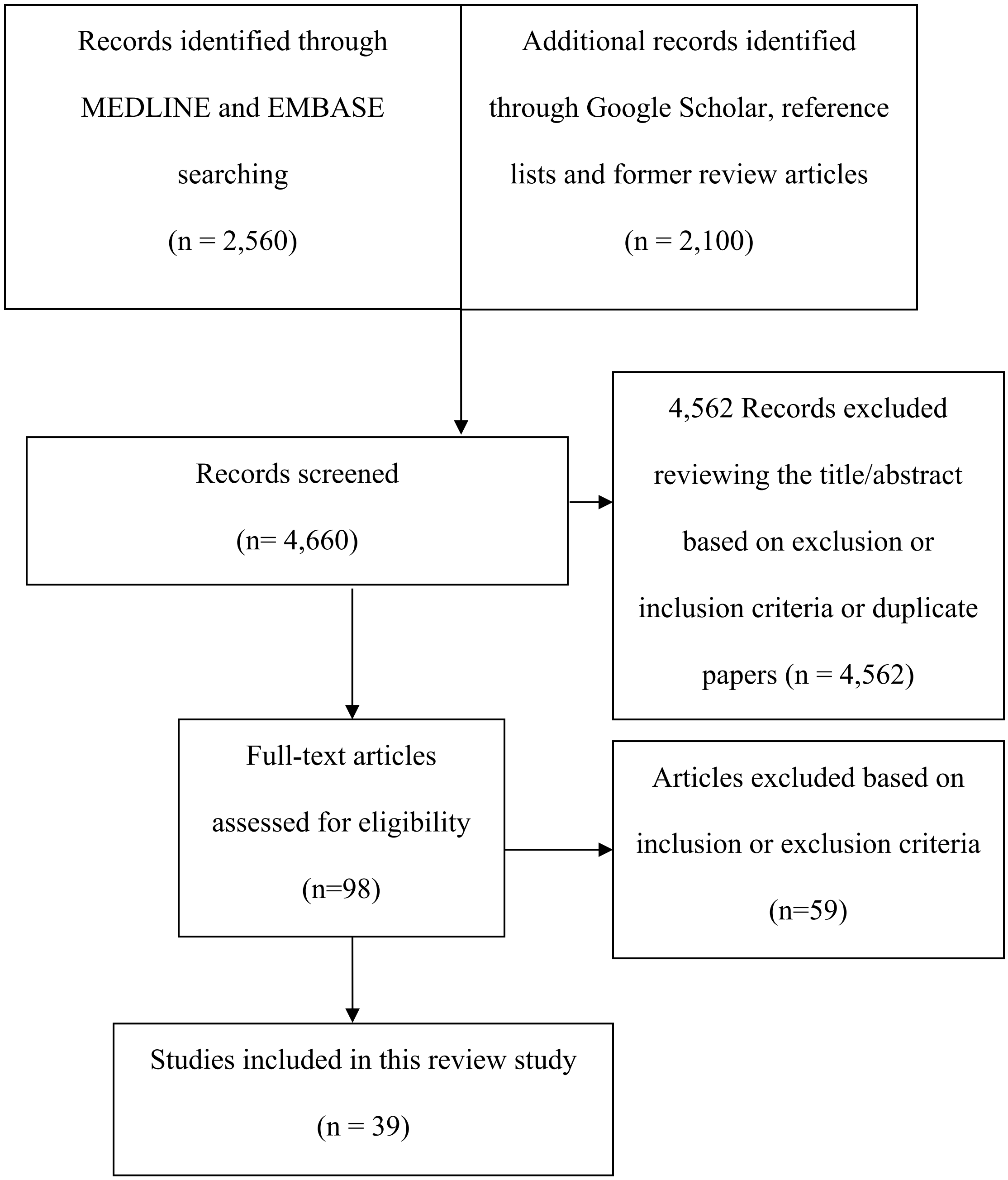

Figure 3. 1. Selection procedure illustrated to extract the relevant articles evaluating the association of metabolic syndrome and dietary patterns.

3.4.2. Study Populations

The general adult population over the ages of 18 years were mainly studied. In addition, the middle-aged and/or elderly population, which included people over 45 years of age, was the focus of four studies (Esmaillzadeh et al., 2007; He et al., 2013; Leite & Nicolosi, 2009; Lutsey et al., 2008). Only two studies (Ambrosini et al., 2010; Pan & Pratt, 2008) evaluated the association between MetS and dietary patterns among adolescents. Five studies included only women (Cho et al., 2011; Esmaillzadeh et al., 2007; Kimokoti et al., 2012; P Saneei et al., 2014; Sonnenberg et al., 2005) one study included only men (Yang et al., 2014) and the remaining included both sexes as their participants.

3.4.3. Measurement of Metabolic Syndrome

The NCEP-ATP III criteria (Expert Panel on Detection, 2001) or its adjusted or modified versions were mainly used to evaluate MetS. However, some studies used the joint 2005 IDF and AHA criteria (Alberti et al., 2009) and other studies used the IDF criteria (Alberti, Zimmet, Shaw, & Group, 2005) to define MetS in the population. Among the adolescent population, MetS was evaluated using the age-adjusted NCEP-ATP III criteria by Pan & Pratt (Pan & Pratt, 2008) and Ambrosini et al., used cluster analysis of the MetS components (Ambrosini et al., 2010).

3.4.4. Determining Dietary Patterns

The dietary patterns were assessed using both a posteriori (i.e., factor analysis and cluster analysis) and a priori analytical approach (index-based) methods.

3.4.4.1. Dietary Patterns Based on A posteriori Analytical Methods

Cluster analysis and factor analysis were the most common a posteriori methods used to determine dietary patterns among different populations. Cluster analysis was used in six articles summarized in Table 3.1. In each of the studies, two to five clusters were extracted. Each of the six studies had clusters representative of a healthy and an unhealthy dietary pattern. The findings of four studies (Berg et al., 2008; Duffey et al., 2012; Leite & Nicolosi, 2009; Sonnenberg et al., 2005) indicated a higher risk of MetS among the populations within the unhealthier clusters compared to the healthier clusters. Seventeen studies used factor analysis method to obtain the patterns prevalent among their study population and to examine the patterns association with MetS prevalence or incidence indicated in Table 3.2. These studies have found two to six dietary patterns for their study population. The dietary patterns extracted among their study populations included “Western/unhealthy”(n=13) (Akter et al., 2013; Ambrosini et al., 2010; Buscemi et al., 2014; Cho et al., 2011; Denova-Gutierrez et al., 2010; Deshmukh-Taskar et al., 2009; DiBello et al., 2009; Esmaillzadeh et al., 2007; He et al., 2013; Heidemann et al., 2011; Lutsey et al., 2008; Naja et al., 2013; Panagiotakos et al., 2007) “Healthy”(n=10) (Akter et al., 2013; Ambrosini et al., 2010; Buscemi et al., 2014; Cho et al., 2011; Denova-Gutierrez et al., 2010; Deshmukh-Taskar et al., 2009; Esmaillzadeh et al., 2007; Heidemann et al., 2011; Lutsey et al., 2008; Panagiotakos et al., 2007) and “Traditional”(n=6) (Barbaresko et al., 2014; Cho et al., 2011; DiBello et al., 2009; Esmaillzadeh et al., 2007; He et al., 2013; Naja et al., 2013) dietary patterns. The dietary patterns observed in three of the studies were unclear (Fonseca et al., 2012; Hong et al., 2012; Kim & Jo, 2011); therefore, were not included in this classification (summarized at the bottom of Table 3.2). Based on these studies, the “Healthy” patterns were characterized by high intakes of vegetables, fruits, legumes, whole grains, and fish. The unhealthy or the so-called “Western” dietary pattern mainly constituted red/processed meat, refined grains, sweets, SSB and processed food, which resembled an unhealthy diet. The “Traditional” dietary patterns were specific for each country, for example, Lebanese, Korean or German “Traditional” dietary pattern. Further, findings of ten studies, which had found a “Western/Unhealthy” dietary pattern among their population, had also found a direct association between this type of dietary pattern and MetS risk (Akter et al., 2013; Ambrosini et al., 2010; Denova-Gutierrez et al., 2010; DiBello et al., 2009; Esmaillzadeh et al., 2007; He et al., 2013; Heidemann et al., 2011; Lutsey et al., 2008; Naja et al., 2013; Panagiotakos et al., 2007). Findings of four out of 10 studies, which found a “Healthy” dietary pattern among their population, indicated an inverse association between the healthy dietary patterns and risk of MetS (Cho et al., 2011; Deshmukh-Taskar et al., 2009; Esmaillzadeh et al., 2007; Panagiotakos et al., 2007). Regarding the third most common pattern, the “Traditional” dietary pattern, mixed results showing both inverse (DiBello et al., 2009; He et al., 2013) and direct (Barbaresko et al., 2014; He et al., 2013) association between this type of diet and MetS were obtained. Other dietary patterns similar to the “Western” dietary pattern were found by the researchers named as “High glycemic index and high fat” (Panagiotakos et al., 2007), “Modern” (DiBello et al., 2009), “Processed foods” (Heidemann et al., 2011) and “Fast food/desserts”(Naja et al., 2013) dietary patterns.

In the aforementioned studies, the analysis was adjusted for common potential confounders including age, sex, socioeconomic status, energy intake, physical activity, BMI, smoking status, self-reported history or family history of chronic diseases and medication usage.

3.4.4.2. Dietary Patterns Based on A priori Analytical Methods

Sixteen studies (Alvarez Leon et al., 2006; Fogli-Cawley et al., 2007; Gouveri et al., 2011; Gregory et al., 2009; Hosseini-Esfahani et al., 2010; Kesse-Guyot et al., 2013; Kouki et al., 2012; Pan & Pratt, 2008; Pimenta et al., 2015; Rizzo et al., 2011; Rumawas et al., 2009; P Saneei et al., 2014; Shang et al., 2011; Thanopoulou et al., 2006; Tzima et al., 2009; Yang et al., 2014) indicated in Table 3.3, used the a priori scoring method to investigate the relationship of MetS and dietary patterns. These studies used different scoring methods to obtain an overall diet score for each individual in the population. The following score-based methods and indices were used:

Alternative Healthy Eating Index-2006 (Pimenta et al., 2015), Dietary Approaches to Stop Hypertension (DASH) (Pimenta et al., 2015; P Saneei et al., 2014), Dietary Guidelines for Americans Index (Fogli-Cawley et al., 2007; Hosseini-Esfahani et al., 2010; Pimenta et al., 2015), Dietary Inflammatory Index (Pimenta et al., 2015), Diet Quality Index-International (Gregory et al., 2009; Pimenta et al., 2015), Healthy Eating Index-1995 (Pan & Pratt, 2008), MedDiet score (Gouveri et al., 2011; Tzima et al., 2009), Mediterranean Adequacy Index (Pimenta et al., 2015), Mediterranean Diet Quality Index (Pimenta et al., 2015), Mediterranean Diet Score (Kesse-Guyot et al., 2013; Pimenta et al., 2015), Mediterranean Food Pattern (Pimenta et al., 2015), Mediterranean Score (Kesse-Guyot et al., 2013), Mediterranean-Style Dietary Pattern Score (Kesse-Guyot et al., 2013), Modified Mediterranean Diet Score (Pimenta et al., 2015; Yang et al., 2014), Pro-Vegetarian Diet (Pimenta et al., 2015), Recommended Food Score (Gregory et al., 2009), Not Recommended Food Score (Gregory et al., 2009), Total Mediterranean score (Alvarez Leon et al., 2006), Traditional Mediterranean diet score (Thanopoulou et al., 2006) and other vegetarian dietary patterns (Rizzo et al., 2011; Shang et al., 2011).

The studies, which have used the HEI-1995, Dietary Guidelines for Americans Index or indices developed based on the adherence to a vegetarian diet for evaluating their populations' diet quality, have obtained mixed results, indicating a negative association or no significant association between these diets and risk of MetS (Table 3.3). While the two studies using the

DASH diet score indicated the higher the DASH score, the lower the risk of MetS was for their population (Pimenta et al., 2015; Saneei et al., 2014)

The adherence to the Mediterranean diet or pyramid has been evaluated by eight studies (Alvarez Leon et al., 2006; Gouveri et al., 2011; Kesse-Guyot et al., 2013; Pimenta et al., 2015; Rumawas et al., 2009; Thanopoulou et al., 2006; Tzima et al., 2009; Yang et al., 2014). In these studies, the Mediterranean dietary pattern consisted of high intakes of fruits, vegetables, cereals, legumes, fish, nuts, olives and a high ratio of mono-saturated to saturated fats, moderate to low intake of alcohol/wine, dairy, and meat. Five of these studies found that the higher the adherence to the Mediterranean diet the lower the risk of MetS would be (Gouveri et al., 2011; Kesse-Guyot et al., 2013; Rumawas et al., 2009; Tzima et al., 2009; Yang et al., 2014.) The remaining studies did not find any significant results (Alvarez Leon et al., 2006; Pimenta et al., 2015; Thanopoulou et al., 2006).

Table 3. 1. Summary of population-based studies, which have investigated the relationship between dietary patterns, derived using cluster analysis method from 2005-2014.

Reference	Participant description (i.e. population size, age, study design, country)	Clustering methods, number of clusters: name of clusters	Confounders	Association between dietary pattern and MetS (significant results obtained after adjusting for confounders)
Sonnenberg et al. (2005)(Sonnenberg et al., 2005)	T: 1,268, M: 0, F: 1,268, 18-76 y, cross-sectional, U.S.	Wards, five clusters: 1) Heart Healthier, 2) Lighter Eating, 3) Wine and Moderate Eating, 4) Higher Fat, 5) Empty Calorie	Age, apolipoprotein E status, smoking, PA and menopausal status	"Empty Calorie" cluster contributes to significantly higher MetS prevalence than other clusters.
Berg et al. (2008)(Berg et al., 2008)	T: 3, 412, M: 1,610, F: 1,802, 25-74 y, cross-sectional, Sweden	K-means, five clusters: 1) Healthy, 2) Sweet, 3) Coffee, 4) Traditional, 5) Fast Energy	Sex (stratified), age, smoking, PA and education	Compared to the "Healthy" cluster, the "Fast Energy" cluster had a direct association with MetS prevalence.
Leite et al. (2009)(Leite & Nicolosi, 2009)	T: 1,052, M: 527, F: 525, 42-74 y, cross-sectional, Italy	K-means, five clusters: 1) Common, 2) Animal products, 3) Starch, 4) Vegetal/fat, 5) Vitamin/Fiber	Age, gender, education, smoking, alcohol consumption and the degree of PA (BMI was also used to stratify results)	The "Starch" cluster had the highest and the "Vitamin/Fiber" and "Vegetal/Fat" clusters had the lowest MetS prevalence.
Duffey et al. (2012)(Duffey et al., 2012)	T: 3,728, M/F, 18-30 y, 20-y FUP, longitudinal, U.S.	K-means, two clusters: 1) Prudent, 2) Western	Age, sex, diet beverage consumption, exam center, baseline weight, PA, EI, education, family structure and smoking status (diet beverage intake had an interaction effect)	The "Prudent" cluster had a lower risk of MetS compared to the "Western" cluster.
Kimokoti et al. (2012)(Kimokoti et al., 2012)	T: 1,146, M: 0, F: 1,146, 25-77 y, 7-y FUP, longitudinal, U.S.	Wards, five clusters: 1) Heart Healthier, 2) Lighter Eating, 3) Wine and Moderate Eating, 4) Higher Fat, 5) Empty Calorie	Age, BMI, PA, smoking status, EI and menopausal status	No significant result was obtained.

Song & Joung (2012)(Song & Joung, 2012)	T: 4,730, M: 1,974, F: 2,756, age ≥ 20, cross-sectional, Korea	K-means, three clusters: 1) Traditional, 2) Meat & Alcohol, 3) Korean Healthy	Age, gender, education, region, smoking, and PA	No significant result was obtained.

BMI, body mass index; EI, energy intake; F, female population size; FUP, follow-up period; M, male population size; MetS, metabolic syndrome; PA, physical activity; T, total population size; Y, years.

Table 3. 2. Summary of population-based studies, which have investigated the relationship between dietary patterns, derived using factor analysis method from 2005-2014.

Reference	Participant description (i.e. population size, age, study design, country)	Components/dietary patterns/factors observed	Confounders	Association between dietary pattern and MetS (significant results obtained after adjusting for confounders)
Esmailzadeh et al. (2007)(Esmaillzadeh et al., 2007)	T: 486, M: 0, F: 486, 40-60 y, cross-sectional, Iran	Three dietary patterns: 1) Healthy, 2) Western, 3) Traditional	Age, smoking, PA, menopausal status, current estrogen use, family history of diabetes/stroke, EI and BMI	The "Healthy" dietary pattern had an inverse and "Western" dietary pattern had a direct association with MetS prevalence.
Panagiotakos et al. (2007)(Panagiotakos et al., 2007)	T: 3,042, M: 1,514, F: 1,528, 18-89 y, cross-sectional, Greece	Six components: 1) Healthful food: low-fat products, 2) High glycemic index and high-fat pattern, 3) Pasta and Bread, 4) Dairy products and eggs, 5) Sweets, 6) Alcohol	Age, sex, physical inactivity, smoking, years of school, use of medication, BMI and income	The "Health-full Food" pattern had an inverse association, while the "High glycemic index and high-fat pattern" and the "Alcohol" pattern had a direct association with MetS prevalence.
Lutsey et al. (2008)(Lutsey et al., 2008)	T: 9,514, M: 4,196, F: 5,318, 45-64 y, 9-y FUP, longitudinal, U.S.	Two factors: 1) Western, 2) Prudent	Age, sex, center, education, race, smoking, pack-years and PA	The "Western" dietary pattern had a direct association with MetS risk.
Ambrosini et al. (2009)(Ambrosini et al., 2010)	T: 1,139, M: 593, F: 546, 14 y, cross-sectional, Australia	Two dietary patterns: 1) Healthy pattern, 2) Western pattern	Sex, maternal education (mothers), being in a two-parent family, hours spent watching television, aerobic fitness and EI	The "Western" dietary pattern was observed to have a direct association with MetS prevalence among females.

Deshmukh-Taskar et al. (2009)(Deshmukh-Taskar et al., 2009)	T: 995, M: 388, F: 607, 19-39 y, cross-sectional, U.S.	Two dietary patterns: 1) Western, 2) Prudent	Age, EI, gender, ethnicity, gender, SES, marital status, PA, smoking, alcohol consumption, and BMI	The “Prudent” dietary pattern had an inverse association with MetS prevalence.
DiBello et al. (2009)(DiBello et al., 2009)	T: 785, M/F, age ≥ 18 y, cross-sectional, Samao	Three factors: 1) Neo-traditional pattern, 2) Modern pattern, 3) Meat and coconut products	Age, sex, material lifestyle score, current smoking status, PA, EI, diabetes medication use and hypertension medication use	The “Neo-traditional” dietary pattern had an inverse, and “Modern” dietary pattern had a direct association with MetS prevalence.
Denova-Gutie´rez et al. (2010)(Denova-Gutierrez et al., 2010)	T: 5,240, M: 1,489, F: 3,751, 20-70 y, cross-sectional, Mexico	Three dietary patterns: 1) Prudent, 2) Western, 3) High protein/fat	Age, sex, PA, place of residence, weight changes, cigarette smoking, estrogen use, menopausal status, and EI	The “Western” dietary patterns had a direct association with MetS prevalence.
Cho et al. (2011)(Cho et al., 2011)	T: 4984, M: 0, F: 4984, 30-79 y, cross-sectional, Korea	Three factors: 1) Western, 2) Healthy, 3) Traditional	Age	The “Healthy” dietary patterns had an inverse association with MetS prevalence.
Heidemann et al. (2011)(Heidemann et al., 2011)	T: 4,025, M: 1,761, F: 2,264, 18-79 y, cross-sectional, Germany	Two dietary patterns: 1) Processed food pattern, 2) Health-conscious pattern	Age, sex, EI, SES, sport activity, smoking status.	The “Processed food pattern” had a direct association with MetS prevalence.
Akter et al. (2013)(Akter et al., 2013)	T: 460, M: 284, F: 176, 21-67 y, cross-sectional, Japan	Three factors: 1) Healthy Japanese dietary, 2) Animal food, 3) Westernized breakfast	Age, sex, workplace, marital status, job position, occupational, physical activity, current smoking, and non-occupational PA	The “Westernized breakfast” pattern had a direct association with MetS prevalence.

He et al. (2013)(He et al., 2013)	T: 20,827, M: 9,936, F: 10,891, 45-69 y, cross-sectional, China	Three patterns: 1) Yellow Earth, 2) Green Water, 3) Western/New Affluence	Age, sex, rural/urban, family income, educational level, current smoking, drinking, PA (had interaction effect), cooking salt/salted vegetable consumption, EI, family history of hypertension, family history of diabetes and BMI	Compared to the "Green Water" pattern, the "Yellow Earth" and the "Western/Affluence" had a direct association with MetS prevalence.
Naja et al. (2013)(Naja et al., 2013)	T: 323, M: 160, F: 163, age ≥ 18, cross-sectional, Lebanon	Three patterns: 1) Fast Food/Dessert, 2) Traditional Lebanese 3) High Protein	Age, sex, marital status, education, crowding index, PA, and smoking	The "Fast Food/Dessert" dietary pattern had a direct association with MetS prevalence.
Barbaresko et al. (2014)(Barbaresko et al., 2014)	T: 905, M: 517, F: 390, 25-82 y, cross-sectional, Germany	Two dietary patterns: 1) German Traditional, 2) name not indicated	Age, sex, education, smoking, PA, total energy and study cohort	The "German Traditional" dietary pattern had a direct association with MetS prevalence.
Buscemi et al. (2014)(Buscemi et al., 2014)	T: 477, M: 167, F: 310, age ≥ 18, cross-sectional, Italy	Three patterns: 1) Unhealthy, 2) Healthy, 3) Intermediate	Age, gender, dietary cluster and PA	No significant association observed.
Studies not included in the results and discussion				
Kim & Jo (2011)(Kim & Jo, 2011)	T: 9,850, M/F, age ≥ 19, cross –sectional, Korea	Four dietary patterns: 1) White rice and kimchi pattern, 2) Meat and alcohol pattern, 3) High fat, sweets, and	Age, sex, BMI, EI, alcohol intake, smoking status, and PA	The "Grains, vegetables, and fish" dietary pattern had an inverse association with MetS prevalence.

		coffee pattern, 4) Grains, vegetables, and fish pattern		
Fonseca et al. (2012)(Fonseca et al., 2012)	T: 2,167, M: 837, F: 1,330, age > 64 y, cross-sectional, Portugal	Four Patterns: 1) for both sex: Healthy, 2) for females: Low fruit and vegetables, for male: Fish, 3) for both sex: Red meat and alcohol, 4) for females: In the transition to fast-food, for males: Intermediate	Age, EI, education, BMI, PA, smoking, alcohol consumption and menopausal status (in women) (sex was stratified)	Women with the “Red Meat and Alcohol” dietary pattern had a higher MetS prevalence compared to the women with “Healthy” dietary pattern.
Hong et al. (2012)(Hong et al., 2012)	T: 406, M: 264, F: 142, 22-78 y, cross-sectional, Korea	Four patterns: 1) Korean traditional, 2) Alcohol and meats, 3) Sweets and fast foods, 4) Fruit and dairy	Age, sex, medications, smoking status, physical activity, and BMI	The “Korean Traditional” dietary pattern had a direct and the “Fruit and Dairy” dietary pattern had an inverse association with MetS prevalence.

BMI, body mass index; EI, energy intake; F, female population size; FUP, follow-up period; M, male population size; MetS, metabolic syndrome; PA, physical activity; SES, socio-economic status; T, total population size;

Table 3. 3. Summary of population-based studies, which have investigated the relationsh ip between a-priori dietary patterns and metabolic syndrome from 2005-2014.

Reference	Participant description (i.e. population size, age, study design, country)	Name, Basic, # of components, score ranges of a priory approach	Confounders	Association found between dietary pattern and MetS (significant results indicated after adjusting for confounders)
Mediterranean diet based indices				
A´lvarez Leo´n et al. (2006)(Alvarez Leon et al., 2006)	T: 578, M: 249, F: 329, age >18, cross-sectional, Spain	Total Mediterranean score, based on adherence to the Mediterranean diet, 10 components, score ranges from 10 to 30 points.	Sex, age, educational level, PA, BMI, diet in the past 12 months, EI and tobacco consumption	No significant result was obtained.
Thanopoulou et al. (2006)(Thanopoulou et al., 2006)	T: 1833, M: 916, F: 917, 20-74 y, cross-sectional, five Mediterranean countries	Traditional Mediterranean diet, based on the adherence to the traditional Mediterranean diet, nine components,	Age, sex and total calories	No significant result was obtained.

		score ≥ 5, scores range from zero to nine points.(Trichopoulou et al., 1995)		
Rumawas et al. (2009)(Rumawas et al., 2009)	T: 1,918, M: 798, F: 1,120, mean age 54 y, 7-y FUP, longitudinal, U.S.	Mediterranean-style dietary pattern score, based on the Mediterranean, diet pyramid, 13 components, score range zero to 100 points.	Age, sex, EI, smoking dose, BMI, and change in BMI among participants without MetS at the baseline	Inverse
Tzima et al. (2009)(Tzima et al., 2009)	T: 3042, M: 1514, F: 1528, 18-89 y, cross-sectional, Greece	MedDiet Score,(Panagiotakos, Pitsavos, & Stefanadis, 2006) based on the Mediterranean diet, 16 components, score ranges from 0 to 55 points.	Age, sex, BMI, smoking habits, PA status	Inverse
Gouveri et al. (2011)(Gouveri et al., 2011)	T: 2,074, M: 900, F: 1,174, age>18 y, cross-sectional, Greece	MedDiet, based on the traditional Mediterranean diet, 11 components, score ranges zero to 55.	Age, sex, smoking, light PA, serum levels of LDL cholesterol and γ-glutamyl transferase, cardiovascular diseases, diabetes mellitus, and hyperlipidemia	Inverse

			and/or family history of hypertension	
Kesse-Guyot et al. (2013)(Kesse-Guyot et al., 2013)	T: 3,232, M: 2,105, F: 1,127, adult, 6-y FUP, longitudinal, France	Mediterranean dietary patterns: 1) MDS, included 10 components and score ranges from zero to nine points; 2) MED score, included 12 components and score ranges from zero to 12 points; 3) MSDPS, included 13 components and score ranges from zero to 100 points.	Age, gender, total daily energy, number of 24-h recall dietary records, baseline smoking status, baseline PA, education level, treatment allocation group and baseline BMI	1) MDS: inverse (stronger association with MetS compared to MED); 2) MED: inverse; 3) MSDPS: inverse (borderline significance)
Yang et al. (2014)(Yang et al., 2014)	T: 780, M: 780, F: 0, age $\geq$ 18, cross-sectional, U.S.	MMDS, based on Mediterranean diet, score ranges from zero to 42 points.	Age & PA	Inverse
HEI-1995, DASH, DGAI, and other indices				
Fogli-Cawley et al. (2007)(Fogli-Cawley et al., 2007)	T: 3,177, M: 1,493, F: 1,684, 26-82 y, cross-sectional, U.S	DGAI*, based on the 2005 Dietary Guidelines for Americans, includes 20 components.	Age (stratified with a cut-off of 55 years), sex, current smoking, current multivitamin	1) If participants with the need of treatment were excluded: inverse; 2) if age $<$ 55 y: inverse

			supplement use, PA, and EI	
Pan & Pratt (2008)(Pan & Pratt, 2008)	T: 4,450, M: 2,260, F: 2,190, 12-19 y, cross-sectional, U.S.	HEI-1995† (T KENNEDY, Ohls, Carlson, & Fleming, 1995)based on the Food Guide Pyramid, 10 components, score ranges from zero to 100 points.	Age, sex, ethnicity, poverty status, BMI and PA	Overall HEI-1995: inverse (Not observed significant association with odds in logistic regression)
Gregory et al., (2009)(Gregory et al., 2009)	T: 1220, M: 469, F: 751, 25-42 y, cross-sectional, Guatemala	Recommended Food Score, Not Recommended Food Score, Food Variety Score and the Dietary Quality Index-International	Age, smoking, physical activity level and residence	No significant result was obtained.
Hosseini-Esfahani et al. (2010)(Hosseini-Esfahani et al., 2010)	T: 2,504, M: 1,120, F: 1,384, 19-70 y, cross-sectional, Iran	DGAI 2005, 11 items are related to the calorie-specific “food group recommendation,” and eight items assess the “healthy choice recommendation, the alcohol consumption item was excluded.	Age, sex, EI, smoking status, and PA	Inverse

Kouki et al. (2012)(Kouki et al., 2012)	T: 1334, M: 663, F: 671, 57-58 y, cross-sectional, Finland	Five grade Diet Score, scored based on achieving adherence to the four following nutritional recommendations: ≥400 g of vegetables per day, ≥2 servings of fish per week, ≥14 g of fibre per 1000 kcal, and <10 E% of saturated fatty acids.	Age, gender, smoking, alcohol consumption, education, prevalent diseases, cognitive function, depression, as well as medications and maximal oxygen uptake tertiles	Inverse
Saneei et al. (2014)(Saneei et al., 2014)	T: 420, M: 0, F: 420, age > 30 y, cross-sectional, Iran	DASH[‡], based on the DASH diet, eight components, score ranges from eight to 40 points.	Age, EI, current oral contraceptive use, current corticosteroid use, PA, marital status, menopausal status, socioeconomic status and BMI	Inverse
Vegetarian dietary patterns				
Rizzo et al. (2011)(Rizzo et al., 2011)	T: 773, M/F, 30-94 y, cross-sectional, U.S.	Vegetarian dietary pattern assessment with the following classifications: 1) Vegetarian: intake of meat, fish or poultry less than once per month; 2) Semi-vegetarian:	Age, sex, ethnicity, smoking, alcohol intake, PA and EI	Vegetarians had lower MetS prevalence compared to non-vegetarians.

		intake of any amount of fish, but less than one time per month of other meat; 3) Non-vegetarian: intake of more than one time per month of red meat or poultry and a total of more than one time per week of all meats.		
Shang et al. (2011)(Shang et al., 2011)	T: 93,209, M/F, 3.75 y FUP, longitudinal, Taiwan	Classified participants based on meat, fish, dairy products and egg consumption to the following four dietary patterns: 1) Non-vegetarians, 2) Pesco-vegetarians, 3) Lacto-vegetarians, 4) Vegans	Sex, age, education status, smoking status, drinking status, physical activity at work and leisure	The risk of MetS was higher for Vegans than for Non-vegetarians, Pesco-vegetarians, and Lacto-vegetarians
Pimenta et al. (2014)(Pimenta et al., 2015)	T: 6,851, M/F, mean age: 30 y, 8.3 y FUP, longitudinal, Spain	1) Pro-Vegetarian Diet,[§] based on a diet, which constitutes plant rather than animal origin. Seven plant and five animal origin food groups were considered.	Age, sex, smoking status, alcohol consumption, PA, time spent viewing television, EI, use of special diets, snacking between main meals, changes in weight over the	1) Inverse; 2) stratified for alcohol intake: only if low intake of alcohol: inverse, for dietary patterns; 3-13: no

	Scores ranged from 12 to 60 points; 2) DASH score: Based on adherence to DASH, includes eight components, scores range from eight to 40 points; 3-8) Six Mediterranean diet based score methods including the following: the MDS, MMDS, MAI, MDQI, MFP, and MED; 9) DQI; 10) HEI-1995; 11) AHEI-2006; 12) DGAI: 13) DII	last 5 years prior to the study and BMI	significant result was obtained.

AHEI-2006, Alternative Healthy Eating Index-2006; BMI, body mass index; DASH, Dietary Approaches to Stop Hypertension; DGAI, Dietary Guidelines for Americans Index; DII, Dietary Inflammatory Index; DQI, Diet Quality Index-International; EI, energy intake; F, female population size; FUP, follow-up period; HEI-1995, Healthy Eating Index-1995; LDL, low density lipoprotein; M, male population size; MAI, Mediterranean Adequacy Index; MDQI, Mediterranean Diet Quality Index; MDS, Mediterranean Diet Score; MED, Mediterranean Score; MetS, metabolic syndrome; MFP, Mediterranean Food Pattern; MMDS, Modified Mediterranean Diet Score; MSDPS, Mediterranean Style Dietary Pattern Score; PA, physical activity; T, total population size; Y, years;

* Another dietary index developed to assess the dietary pattern of the individual in epidemiological studies is the Dietary Guidelines for Americans Index. This dietary index is developed based on the adherence to the Dietary Guidelines for Americans. The purpose of the Dietary Guidelines for Americans guidelines is to reduce the risk of chronic conditions such as cardiovascular diseases. This index includes 20 categories within two main components. The first component is related to the recommendations regarding the intake of calorie-specific food groups, which includes 11 categories. These items include fruits; five vegetable sub-groups; a variety of vegetables; grains; milk and milk

products; meat and legumes; and discretionary calories. The second component is the healthy choice or nutrient intake recommendations that includes nine categories. The items are as follows: fiber intake; percentage of grains that are whole grain; sodium intake; alcohol consumption; five recommendations related to fat and cholesterol intake, including, total fat and saturated fat as a percentage of calories, low-fat milk and meat choices, trans fat intake and cholesterol intake (Fogli-Cawley et al., 2007).

† One dietary index developed based on the adherence to the Food Guide Pyramid is the Healthy Eating Index. This index includes the sum of scores from the following 10 components: grains, vegetables, fruits, milk, meat or meat alternatives, total fat intake, saturated fat, cholesterol, sodium and diet variety. The scores range from zero to 100, with higher scores indicating a better diet quality (Kennedy et al., 1995).

‡ The Dietary Approaches to Stop Hypertension (DASH) score is based on the adherence to the DASH diet plan developed to control specific chronic conditions including hypertension. The scoring method to evaluate the adherence to DASH was based on the consumption of eight food catagories as either adequate or inadequate foods. The eight components were as follows: high intake of fruits; vegetables; nuts and legumes; low-fat dairy products; whole grains and low intake of sodium, sweetened beverages, and red and processed meats. The sum of the scores ranged from eight to 40 points, with the higher scores indicating a greater adherence. The DASH diet is mainly investigated in randomized controlled studies (Al-Solaiman et al., 2010; Saneei, Hashemipour, Kelishadi, Rajaei, & Esmaillzadeh, 2013).

§ Pro-Vegetarian Diet is a diet based on plants rather than food derived from animals. Seven plant and five animal origin food groups were considered. The score of this diet ranges from 12 to 60, higher scores indicating better adherence to this diet. The results showed an inverse association between Pro-Vegetarian Diet scores and MetS incidence (Pimenta et al., 2015)

3.5. Discussion

Based on the search strategy of this study, 39 population-based studies were identified that investigated the association of MetS and dietary patterns. Findings of our study showed that population-based studies had been conducted in different countries especially in the European and North American countries, on adult populations of both sexes. These studies tended to use the factor analysis method and also the a priori dietary approaches such as the Mediterranean dietary pattern. Based on this review of the population-based studies, the Mediterranean diet and the "Western" dietary pattern seemed to be the two extremes of the MetS and diet association continuum.

The relationship between MetS components and CVD is established from early stages of life and remains until adulthood. Therefore, it is essential to identify and investigate the presence of MetS in children and adolescents (Rosenberg, Moran, & Sinaiko, 2005). Based on the findings of this review study a gap exists in the investigation of MetS among adolescents and children. This gap is a consequence of recommendations by authoritative bodies to investigate MetS only among individuals above the age of 10 years; as well, there remains an inconsistency in MetS definitions used by researchers working with children and adolescents (Ford, Ajani, & Mokdad, 2005; Jolliffe & Janssen, 2007; Zimmet et al., 2007). The methodological approach in determining the dietary pattern of a population, whether a priori or a posteriori, was chosen based on the research question. However, researchers did not explain the reason behind the choice of methodological approach in a posteriori methods. Those who used the a priori methods indicated that assessing adherence to the specific diet through its relevant index was the reasoning behind their choice.

3.5.1. The A posterior Analytical Methods

Among the aforementioned possible a posteriori approaches, the factor analysis and cluster analysis were the most common methods used in the epidemiological studies included in this review and similarly indicated by Newby and Tucker (Newby & Tucker, 2004). In factor analysis, the dietary patterns are determined by statistically evaluating the correlation between the entering variables, which generate discrete factors from similar input variables (Oddy et al., 2013). While cluster analysis is a method in which individuals with similar dietary characteristics are aggregated into one categorical cluster (Hu, 2002). These methods extract the actual dietary patterns of the populations. However, the disadvantage of these two commonly used methods is their subjectivity and that they do not account for the disease risk (Hoffmann et al., 2004). An approach that derives dietary patterns based on the disease risk is the RRR method, which has been introduced to nutritional epidemiology by Hoffmann et al. in 2004 (Hoffmann et al., 2004). This method is mainly based on the scientific evidence of disease-specific response variables, which may be the components of a disease or nutrients related to a disease (Hoffmann et al., 2004). To our knowledge, three studies (Barbaresko et al., 2014; Liu et al., 2009; Yeh, Chang, & Pan, 2011) have used the RRR method, which focuses on nutrients or MetS components as dependent variables to investigate the association between MetS and diet. Therefore, based on the aim, to have real-world dietary patterns or dietary patterns related to a specific disease risk, researchers have to choose one of these empirical, analytical methods (Hoffmann et al., 2004). Researchers should consider potential limitations when applying a posteriori methods including the limited reproducibility due to several decision-making points and the limited data available regarding the validity of this approach in epidemiological studies (Moeller et al., 2007).

In nearly all studies, which have used factor analysis or cluster analysis, both a “Western/Unhealthy” and a “Healthy/Prudent” dietary pattern were observed to be prevalent among their study populations. As for the “Western/Unhealthy” dietary pattern and similar dietary patterns such as “Energy Dense”, “Fast Energy”, “Empty Calorie” and “Modern” patterns showed to have a direct association with MetS status in most of the studies. Even though in some of the studies indicated in Tables 3.1 and 3.2, researchers have adjusted for BMI, weight change, energy intake, physical activity and smoking status as a potential confounder; the association remained significant. This suggests that the effect of the “Western/Unhealthy” dietary pattern on MetS status is beyond the effect of anthropometric and other lifestyle factors as similarly indicated by Calton et al. (Calton, James, Pannu, & Soares, 2014). Previous evidence suggests high intakes of refined grains, sugar, saturated fats and low intake of fruits and vegetables increases the risk of MetS by increasing inflammation (Giugliano, Ceriello, & Esposito, 2006). This can be one explanation to the associations observed among dietary patterns and MetS. Further, findings of only four of these studies have indicated an inverse association between the “Healthy” dietary pattern and MetS.

3.5.2. The A priori Analytical Methods

The overall aim of the a priori approach is to compare and classify the population into categories based on their adherence to recommendations or well-known healthy diets (Panagiotakos, 2008) This score-based method is used to indicate the characteristics of the overall diet (Davenport et al., 1995; Garriguet, 2009). While this method is more reproducible compared to the a posteriori methods (Moeller et al., 2007), the disadvantage of using recommendations to develop an index of diet quality is that the index score is the sum of the points allocated to each of the components of the index. The inter-correlation of the score components with one another may have not been proven. Hence, a total score is not representative of the overall effect of the diet (Hoffmann et al., 2004). Studies included in this review that have used the Healthy Eating Index-1995, Dietary Guidelines for Americans Index and the vegetarian dietary patterns observed mixed results, which indicate the need for further research.

In addition to the recommendation based indices, dietary patterns such as the Mediterranean diet, initially identified via a posterioi methods, have been used to develop indices with the aim of evaluating the adherence to these healthy-known dietary patterns (Bountziouka, Tzavelas, Polychronopoulos, Constantinidis, & Panagiotakos, 2011; Panagiotakos, 2008). Eight studies included here (Table 3.3), have used different indices developed based on the Mediterranean diet. Five of these studies have indicated the higher the adherence to this diet the lower risk of MetS. This may be evidence to the reproducibility and validity of this diet as a beneficial diet for preventing MetS. Similar to our results, the preventative impact of the Mediterranean diet on MetS has been proven in interventional studies (Jones, Park, Lee, Lerman, & Fernandez, 2011). As well, a systematic review study conducted on observational and RCT studies has concluded that Mediterranean diet reduces the risk of MetS (Kastorini et al., 2011) This nutrient-dense diet not only targets weight loss but also reduces the levels of inflammatory biomarkers and atherogenic lipoproteins due to its high phytonutrient and beneficial fatty acid contents (Andersen & Fernandez, 2013). More studies have observed the protective effect of the Mediterranean diet (five out of eight) compared to studies that evaluated the “prudent/healthy” dietary pattern (four out of 10). This may be due to the emphasis on higher intakes of nuts, olive/olive oil, mono-saturated to saturated ratio and moderate intakes of alcohol/wine in the Mediterranean diet compared to the “prudent/healthy” dietary pattern. A similar association between DASH and MetS was observed in two studies (Pimenta et al., 2015; Saneei et al., 2014). An RCT study has conclusively demonstrated that the DASH diet has an improving impact on the MetS status compared to not only a normal control diet but also a weight-reducing diet (Azadbakht, Mirmiran, & Azizi, 2005). Although the Mediterranean diet seems to have a higher fat content compared to the DASH diet (Calton et al., 2014) the promising results from the included population-based studies indicate that both diets have contributed to a lower risk of MetS prevalence and incidence.

3.5.3. The Mediterranean and the "Western" Dietary Patterns

Based on this review of the population-based studies, the Mediterranean diet and the "Western" dietary pattern seem to be the two most common extracted dietary patterns having a significant association with MetS. The different effect of the two diets on MetS reflects the opposite impact of their components on MetS. Based on these studies, the Mediterranean diet is defined as a diet high in whole grains, fruits and vegetables, fish, legumes, nuts, mono-saturated fats and olive oil and moderate to low intake of meat, dairy products, and alcohol. Whereas, the "Western" dietary pattern is characterized by high intakes of red/processed meat, fast food, refined grains/cereals, SSB, eggs, sweets/desserts and low intake of fruit and vegetables, and dairy products. While the Mediterranean diet consists of high intakes of fiber and whole grains, the "Western" dietary pattern constitutes of high intakes of refined grains. The effect of whole grains and high fiber on the waist circumference component of the MetS has been observed in epidemiological studies. The inverse association between MetS and whole grains intake may be due to the impact of whole grain consumption on the components of MetS such as HDL-C (Jacobs & Gallaher, 2004). On the other hand, intake of refined grains contributes to a high glycemic index, which could increase the risk of MetS. Findings from a study conducted among older adults indicated an inverse and direct association for whole and refined grains, respectively (Sahyoun, Jacques, Zhang, Juan, & McKeown, 2006).

The Mediterranean diet has a moderate to low intake of red meat, while in the "Western" dietary pattern a high intake of red/processed meats are observed. The association of MetS status and meat has been evaluated in a few studies (Azadbakht & Esmaillzadeh, 2009; Damião, Castro, Cardoso, Gimeno, & Ferreira, 2006; Lutsey et al., 2008). Regarding red meat, most studies have yielded a direct association between MetS and meat intake. Results of the Atherosclerosis Risk in Communities Study indicated that meat products such as hamburger, hotdogs and processed meats increase the risk of MetS (Lutsey et al., 2008). The increasing risk of MetS with higher meat consumption could be due to the high saturated fat content of meat and its association with MetS components such as blood pressure and abdominal obesity (Lutsey et al., 2008).

The Mediterranean diet is rich in fruits and vegetables while the “Western” dietary pattern, is deficient in these foods. The relationship between vegetables and fruit intake and MetS has been assessed in a few studies. A cross-sectional study (Esmaillzadeh et al., 2006) among adult women in Tehran revealed an inverse association. However, in the Atherosclerosis Risk in Communities Study (Lutsey et al., 2008) and a cross-sectional study (Setayeshgar, Whiting, & Vatanparast, 2012) based on CHMS Cycle 1 data, no significant association was observed between fruits and vegetables intake and MetS status. The expected reducing the impact of fruit and vegetables on MetS is due to these foods optimizing the effect on MetS components such as blood pressure (Djousse, Padilla, Nelson, Gaziano, & Mukamal, 2010; Lutsey et al., 2008) or fasting plasma glucose (Calton et al., 2014). Further research is required in this area to reveal the impact of this food group on MetS, which may have been obscured due to including foods such as potatoes within the vegetables group.

Based on this review study, 12 studies (Ambrosini et al., 2010; Berg et al., 2008; Buscemi et al., 2014; Denova-Gutierrez et al., 2010; Deshmukh-Taskar et al., 2009; DiBello et al., 2009; Duffey et al., 2012; Heidemann et al., 2011; Kimokoti et al., 2012; Lutsey et al., 2008; Panagiotakos et al., 2007; Sonnenberg et al., 2005) have found a “Western/Unhealthy” dietary pattern prevalent in Westernized countries of the world. None of these studies indicated a high intake of alcohol as a characterizing factor of the “Western/Unhealthy” dietary pattern. However, one of these studies (Deshmukh-Taskar et al., 2009) has considered alcohol consumption as a potential confounding factor in the statistical analysis. Four studies among Western populations (Berg et al., 2008; Kimokoti et al., 2012; Panagiotakos et al., 2007; Sonnenberg et al., 2005) have extracted a separate dietary pattern which is characterized by high intakes of alcohol. Two of these studies have indicated a direct association between alcohol dietary pattern and MetS (Fonseca, Gaio, Lopes, & Santos, 2012; Panagiotakos, Pitsavos, Skoumas, & Stefanadis, 2007)

The other components of the Mediterranean diet including olive/olive oil, moderate alcohol/red wine, nuts, legumes, fish also contribute to a high mono-and-poly- saturated fatty acids and anti-oxidant profile, which results in lowering the risk for chronic inflammatory conditions such as MetS (Babio, Bullo, & Salas-Salvado, 2009) For example virgin olive oil has high mono-saturated fat and polyphenol profile, which has an optimal effect on the blood lipids, hypertension, and insulin sensetivity. All these effects contribute to a lower risk of MetS (Babio, Bullo, & Salas-Salvado, 2009). The overall impact of the Mediterranean diet on MetS is related to the impact on each of the MetS components, the anti-inflammatory effect and the impact on insulin resistance which is known to have a significant role in the development of MetS.(Babio et al., 2009) The complexity of this syndrome with multiple components requires a diet that prevents and/or controls the risk such as the Mediterranean diet that attributes to affect all the components of MetS in an optimizing direction (Djousse et al., 2010). Whereas, components of the “Western” diet provokes the MetS components. Thus, in view of the beneficial effects of the Mediterranean diet on MetS, promoting this dietary pattern or its most beneficial components relevant to different populations’ cultural practices may be an effective preventive strategy.

There are limitations that should be considered due to the nature of a review study. First, only English-language studies have been included. However, the included articles are from a variety of countries that their official language is not necessarily English. Further, studies published between 2005 and 2014 have been included in this review, while there are earlier review papers that include studies published before 2005.

3.6. Conclusion

The high worldwide burden of CVD and diabetes as the most common cause of mortality and morbidity has led many researchers across the globe to investigate the link between MetS and diet as a modifiable factor. Findings of studies from 23 countries indicate that “Western”, Mediterranean, “Healthy” and “Traditional” dietary patterns are common diets among adult populations across the globe. Using different MetS criteria, the studies included in this review concluded an association between these dietary patterns and MetS status during adulthood. Since no unified definition of MetS exists for adolescence, it creates challenges in investigating the association between dietary patterns and MetS in this age group.

Findings of this study suggest that the methods used to determine the dietary pattern of a population should be chosen based on the purpose of research. As MetS consists of many components investigation of a dietary pattern is beneficial in understanding the overall effect of diet rather than individual nutrients or food items on MetS. Our scoping review revealed support for diets based on the Mediterranean diet and for the avoidance of the “Western” diet could aid in preventing MetS using population-based studies, which is in agreement with RCTs. Promoting the Mediterranean components among populations where the “Western” dietary pattern is prevalent may be considered.

After reviewing the literature and conducting the scoping review, regarding the association of MetS and dietary patterns, after investigating 39 population-based studies (in scoping review), no studies have been conducted to determine this association among the Canadian adolescent and adult population. In addition, no studies were found to determine the 10-year CVD risk and CAG across the different levels of socio-demographic and lifestyle factors and to evaluate the association of 10-year CVD risk or CAG and dietary patterns. Thus, we aimed at focusing on this gap and addressing the aforementioned objectives for the Canadians population in Study 4 and 5. In the next chapter, we demonstrate the general methodology that was used for Studies 1-5 of this thesis.

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CHAPTER 4: Methodology

In this chapter, the methodology related to the studies included in this thesis is demonstrated. Details specific to each study's methodology are available in the corresponding Study's chapter.

4.1. Comprehensive Review

To address Objective 1, a comprehensive web-based scoping review based on methodology presented by Arksey and O'Malley (2009) was conducted using Medline, Embase and Google Scholar. This study included 39 population-based studies. These studies included in the scoping review were classified as either a priori method users or a posteriori method users based on the dietary pattern extraction method they had used (described in Chapter 3).

4.2. Statistics Canada's Guidelines for Using CHMS Data

4.2.1. Guidelines for Combining CHMS Cycles 1 & 2 Data

For Study 5 to 8, we combined data from CHMS Cycles 1 and 2 to address Objectives 2, 3 and 4. Following the pooled approach, data were combined in the initial step, making one unique dataset, while adjusting for weights (Roberts & Binder, 2009). To ensure that data from the two cycles are consistent, and the data were nationally representative after combining, CHMS files from Statistics Canada were used as follows: "Instructions for Combining Cycle 1 and Cycle 2 CHMS Data" (Statistics Canada, 2014a), "Master file for Cycle 1", "Master file for Cycle 2", "Fasted sub-sample file for Cycle 1", "Fasted sub-sample file for Cycle 2", "Cycles 1 & 2 combined weight files" and "Fasted subsample Cycles 1 & 2 combined weight files". All of these files are available at the Research Data Centers in Canada. The file including the instructions suggests that household, MEC and lab variables are consistent within the two cycles and this document presents steps to follow when combining the cycles. The few inconsistent variables between the cycles are presented in the "Instructions for Combining Cycle 1 and Cycle 2 CHMS Data" (Statistics Canada, 2014a). The response rate was 53.5 % for the combined Cycles 1 and 2 household and MEC and this rate was 47.2 % for the fasted sub-sample (Statistics Canada, 2014a).

4.2.2. Guidelines for Weighting and Bootstrapping in CHMS

Statistics Canada's guidelines for weighting and bootstrapping were applied to the sample to obtain representative estimates of the total population. A certain weight was assigned by Statistics Canada to each respondent. The weight was assigned according to the sample of the population of which the respondent was representative. The assigned weights are equal to the inverse probability of selection. Because CHMS has a double-staged sampling process, including the collection sites and dwelling selections, two different weights have been considered for each respondent. Statistics Canada has multiplied the selection weights and has adjusted the weights for non-response to obtain the final survey weight for each respondent. This final survey weight was used in all analyses of this Thesis. The fasted subsample was selected independently, and a separate weight has been calculated for this subsample by Statistics Canada. To combine data from Cycles 1 and 2, the weight variable from each of the Cycles 1 and 2 data files were removed, and the combined weight files provided by Statistics Canada were used (Statistics Canada, 2014a). Calculating the survey estimate variance is essential, but due to the complex sampling design, the variance cannot be calculated via the usual variance equations. Therefore, a bootstrap method suggested by Statistics Canada was used to conduct an analysis of all CHMS based studies of this thesis. The bootstrapping method is based on 500 times resampling with replacement of "n-1" collection sites from "n" collection sites (Statistics Canada, 2011c).

4.3. Statistical Analysis

4.3.1. Data Cleaning and Management

The CHMS Cycles 1 and 2 data files were merged using instructions provided by Statistics Canada to address each study's objectives. This document recommends following steps/considerations that include: existence of variables in both cycles; the same variable name in both cycles; similar variable concept in both cycles; similar question wordings in both cycles; similar variable population coverage in both cycles; similar response range/categories in both cycles; and there are no notes in Cycle 2 that indicate variables not being comparable between cycles. Thereafter, data manipulation, cleaning, grouping and creating the variables of interest were done. The variables of interest are indicated in Table 4.1. Three types of variables were used to address all objectives of this thesis including the existing variables in CHMS, derived variables by CHMS, and variables which were derived within the present research (Statistics Canada, 2010a, 2014b).

The variables of interest were as follows: age; sex; income; education; physical activity; BMI; waist circumference; systolic and diastolic blood pressure; HDL-C; total cholesterol; triglycerides levels; HbA1c; fasting plasma glucose; having heart disease and or stroke; diabetes status (been told by health professional); antihypertensive medication use; blood lipid-lowering medication use; smoking status; alcohol consumption; BMI, food consumption including meat consumption, milk and dairy products, grains and fruits and vegetables, dietary fat and water and soft drinks. Furthermore, the following outcome variables that will be derived within the present thesis (details indicated in each study/chapter) were created from the existing variables and derived variables by CHMS (the variables used to derive them are indicated in the parenthesis after each derived variable): abdominal obesity (sex, age, ethnicity and waist circumference); diabetes status (been told by health professional and/or HbA1c and/or fasting plasma glucose), MetS (sex, age, ethnicity, waist circumference, blood pressure, HDL-C level, triglyceride level, diabetes status, antihypertensive medication use); 10-year risk of ASCVD (age, sex, ethnicity, blood lipid lowering medication use, systolic blood pressure, antihypertensive medication use, HDL-C level, total cholesterol level, smoking status, diabetes status; Vascular age (age, sex, systolic blood pressure, antihypertensive medication use, HDL-C level, total cholesterol level, smoking status and diabetes status), CAG (chronological age at the clinic); and dietary pattern scores (frequency of food/beverages intake data) (Statistics Canada, 2010a, 2014b).

Table 4. 1. Description of variables of each of the thesis studies including, outcomes, study variables, and covariate.

	Indicator of disease/Outcome derived	Study variables	Covariates/socio-demographic/lifestyle factors
Study 2 Objective 2 6-79y 29,625,300	-	-Food items/food group consumption (derived by the intake per year of food or food group/365 days)	Age (continuous), age groups (6-18 & 19-79y), sex (M,F), household income (lowest, lower middle, upper middle, highest), education (less than secondary school graduation, secondary school graduation, some post-secondary and post-secondary graduation), physical activity (active, moderately active and inactive) and ethnicity (White and non-White)
Study 3 Objective 3 20-79y 23,022,889	Diabetes diagnosed diabetes, undiagnosed diabetes, prediabetes (derived from: “have you been told by health professional” question (y/n) and glycated hemoglobin HbA1c levels)	-Food items/food group consumption (derived by the intake per year of food or food group/365 days)	Age categorical (20-39y, 40-59y and 60-79y), sex (M,F), household income (lowest, lower middle, upper middle, highest), highest household education level (less than secondary school graduation, secondary school graduation, some post-secondary and post-secondary graduation), physical activity (active, moderately active and inactive), ethnicity (White and non-White), smoking (smoker, non-smoker), alcohol intake (ever, never) and ethnicity (White, non-White)

Study 4 Objective 4 12-79y 26,038,108	Metabolic syndrome (derived from sex, age, ethnicity, ethnic-specific waist circumference, blood pressure, high-density lipoprotein cholesterol level, diabetes status, antihypertensive medication usage)	-Food items/Food group consumption (derived by the intake per year of food or food group/365 days) - Dietary pattern (derived by principal component analysis from the 32 food groups indicated in Table 4.2.	Age categorical (12-19, 20-49 and 50-79), sex (M,F), household income (lowest, lower middle, upper middle, highest), highest household education level (less than secondary school graduation, secondary school graduation, some post-secondary and post-secondary graduation), physical activity (active, moderately active and inactive), ethnicity (White and non-White; and White; Aboriginal, Middle East, Mediterranean, Sub-Saharan African, and West Asian; Asian, South Asian and Latin American; and Chinese & Japanese), smoking (current smoker, former smoker, and non-smoker), alcohol intake (ever, never) and ethnicity (White, non-White), having a family doctor (y/n).
Study 5 Objective 4 40-79y 13,655,671	Ten-year risk of Atherosclerotic Cardiovascular Disease (derived from age, sex, ethnicity, total cholesterol level, high-density lipoprotein cholesterol level, systolic blood pressure, blood pressure medication usage, diabetes, and smoking status.)	-Dietary pattern (derived by principal component analysis from the 32 food groups indicated in Table 4.2.	Age continuous, age categorical (40-49, 50-59y, 60-69y, 70-79y), sex (M,F), ethnicity (White/non-White), total cholesterol level, high-density lipoprotein cholesterol level, systolic blood pressure, metabolic syndrome, blood pressure medication usage and lipid-lowering medication use (drug identification numbers),

			immediate family member having premature cardiovascular disease (y/n), diabetes (fasting plasma glucose level of $\geq$ 7 mmol/L or self-reported diagnoses of diabetes by a health professional) and smoking status (smoker vs non-smoker), drinking alcohol (ever/never), having a family doctor (y/n).
	Cardiovascular age gap (derived from age, sex, ethnicity, total cholesterol level, high-density lipoprotein cholesterol level, systolic blood pressure, blood pressure medication usage, diabetes, and smoking status)	- Dietary pattern (derived by principal component analysis from the 32 food groups indicated in Table 4.2.	Age continuous, age categorical (40-49, 50-59y, 60-69y, 70-79y), sex (M,F), ethnicity (White/non-White), total cholesterol level, high-density lipoprotein cholesterol level, systolic blood pressure, metabolic syndrome, blood pressure medication usage and lipid-lowering medication use (drug identification numbers), immediate family member having premature cardiovascular disease (y/n), diabetes (fasting plasma glucose level of $\geq$ 7 mmol/L or self-reported diagnoses of diabetes by a health professional) and smoking status (smoker vs non-smoker), drinking alcohol (ever/never), having a family doctor (y/n).

4.3.2. Lifestyle and Socio-economic Factors

Lifestyle and socio-economic factors were classified or grouped based on each study's objectives to produce the required categories. These factors were used in addressing all the current study's objectives if otherwise used it was indicated in each Study . However, through the analysis, some modifications may have been applied which are indicated for each study in the corresponding chapter. Age was classified into two main categories: adolescents and teenagers (referred to adolescents in this thesis) (12 to 19 years) and adults (20 to 79 years). Data from respondents under 12 years from CHMS have not been used at all in this thesis. Income was measured based on CHMS data of total household income, before taxes and deductions from sources in the past year and considering the number of household members. The derived variables provided by Statistics Canada in the CHMS household questionnaire were used, which included the following four categories: lowest, lower-middle, upper-middle and highest income (Statistics Canada, 2014b).

Education was categorized into the following four levels: less than secondary school graduation, secondary school graduation, some post-secondary and post-secondary graduation. Mainly ethnicity was collapsed into two categories of White and non-White, if otherwise, it is mentioned in the methods section of each Study.

Physical activity was classified as the Physical Activity Index with the following categories: active, moderately active and inactive from the CHMS data set. The total daily leisure-time energy expenditure (DEE) (kcal/day) was used to assign cut-offs for different categories of physical activity (Equation 4.1) as follows: inactive ($0 \leq DEE < 1.5$), moderate activity ($1.5 \leq DEE < 3$) and active ($DEE \geq 3$) levels (Fransoo et l., 2011; Statistics Canada, 2014b).

DEE (Kcal/kg/day) = (T x H x MET value) / 365……………………………………(4.1)

T = number of times a respondent involved in physical activity in the past 12 months

H = average hours of physical activity

MET value = Amount of energy expenditure (kcal/kg per hour) (Statistics Canada, 2014b)

In CHMS, alcohol consumption was considered as a lifestyle factor with the two categories of "ever" used and "never" used alcohol. Moreover, smoking status as another lifestyle factor was classified into two main categories of smokers and non-smokers.

4.3.3. Assessing Diet

In this study, using CHMS Cycles 1 and 2 data we evaluated the intake from food groups and dietary patterns among Canadians. The main part of CHMS dietary data is included in the nutrition theme of the survey. These dietary data were released in Wave 1 of each cycle. The fish-and shellfish-related questions in Cycle 2 of this survey have been excluded from the household questionnaire and were expanded and included in the MEC questionnaire, thus could not be included in studies which data from Cycles 1 and 2 of CHMS were combined (Statistics Canada, 2012a).

4.3.3.1. Dietary Components of the Canadian Health Measures Survey

The CHMS FFQ included 41 questions in the household questionnaire of CHMS. These questions were grouped into six categories of Meat consumption (eight questions); Milk and dairy product consumption (five questions); Grains, fruits and vegetables (13 questions); Dietary fat consumption (two questions); Water and soft drink consumption (10 questions); and Salt consumption (three questions). In CHMS, the FFQ was developed to complement the objective health measures included in the survey. For example the dietary fat questions were to complete the cardiovascular health component of the survey. The respondent was asked to report their intake by indicating a number of times of intake between zero and 500 in addition to a time frame of within a "day, week, month and year". The serving size of intake was not specified. This questionnaire was not validated.

In the Studies (2-5) included in this thesis 32 questions from the CHMS FFQ were included (excluding salt, water and fish and shellfish questions which were not used in this study). The "Water drinking, sources and treatment" variables were excluded due to not fitting in the context of a dietary pattern and the intake being dependent on many variables other than dietary intake such as disease, weather, etc. In addition, three questions related to "Salt consumption" component were excluded in all studeis of this thesis because of the ordinal measurement scale of these (Statistics Canada, 2014). In addition, the frequency of intake per year was divided by 365 to have an average frequency of intake per day in Studies 2-5 (Statistics Canada, 2010a).

4.3.3.2. Food Group Intake

In order to address Objective 2, the CHMS combined dietary intake data from Cycles 1 and 2 were classified into different food groups based on "Eating Well With Canada's Food

Guide" (Health Canada, 2007a) (Table 4.2). These groups include: 1) vegetables and fruits; 2) grains; 3) milk and alternatives; 4) meat and alternatives; and 5) "other food" group including the following subgroups: a) dietary fat; and b) beverages.

Table 4. 2. Grouping of Canadian Health Measures Survey Cycle 1 and 2 dietary intake questions in its Data Dictionary.

Food groups	**i.e., "how often do you usually eat per day/week/month/year?", otherwise, the whole question is asked.**
Meat and Alternatives group	-Beef or pork hot dogs -Cooked dried beans, such as refried beans, baked beans, pea soup or kidney beans, excluding green and yellow beans -Eggs and egg dishes including the yolk (excluding all egg dishes made with only egg whites); egg dishes could include eggs, omelets, frittata or quiche. -Fish- and shellfish-related questions in Cycle 2 -Liver (including all types of the liver such as beef, veal, pork or chicken, but excluding liverwurst and liver pâté) -Other organ meats such as kidneys, heart or giblets -Peanuts, walnuts, seeds, or other nuts, excluding nut butters such as peanut butter -Red meat (beef, hamburger, pork or lamb) -Sausage or bacon (including all types of sausage, such as breakfast, pepperoni, and kielbasa but excluding low-fat, light or turkey varieties)
Milk and Alternatives group	-Cottage cheese -Milk or enriched milk substitutes. Questions are asked about the kinds of milk usually consumed (3.25, 1, 0.5, skim or non-fat), flavoured milk beverages (chocolate milk and flavoured milk beverages such as Oh Henry®, rice, soya and other). -Yogurt, excluding frozen yogurt -Ice cream or frozen yogurt
CHMS questions on Grain products group	-Any kind of pasta (including spaghetti, noodles, macaroni & cheese or pasta salad) -Any kind of rice -Brown bread, including bagels, rolls, pita bread or tortillas -Hot or cold cereal -Instant, seasoned or wild rice (such as Minute Rice®, Dainty®, Rice-a-Roni®) -White bread, including bagels, rolls, pita bread or tortillas

Vegetables and Fruit group	-Fruit (fresh, frozen or canned) -Lettuce or green leafy salad with or without other vegetables -Other than French fries, home fries, or hash brown potatoes, including baked, boiled, mashed or in potato salad, but excluding sweet potatoes -Spinach, mustard greens or collards excluding kale -Tomatoes or tomato sauce, including salsa, tomato soup, and spaghetti sauce but excluding tomato paste, ketchup or pizza sauce -French fries, home fries, or hash brown potatoes -Fruit and vegetables juice (includes fruit juice and vegetables juice) -All other types of vegetables excluding those already mentioned
Dietary fat	-Regular-fat potato chips, tortilla chips or corn chips (excluding low-fat chips and pretzels). -Regular-fat salad dressing or mayonnaise (including on salads and sandwiches)
Beverages	-Diet soft drinks -Sugar-sweetened beverages (includes fruit flavoured drinks, regular soft drinks, sport drinks, such as Gatorade® or PowerAde®) -Fruit and vegetables juice (includes fruit juice and vegetables juice)

4.3.3.3. Overall Diet Assessment

In Study 4 and 5, the dietary patterns prevalent were extracted; therefore, the PCA method was used. This method was chosen based on the research questions and the outcomes of this study. The first aim of Study 4 and 5 were to identify the dietary patterns prevalent among the population and thus the PCA method was the most appropriate method to address this objective compared to cluster analysis and a priori methods. In addition, the outcomes of MetS and CVD risk have uncertain underlying pathophysiology, which make hybrid methods results less interpretable compared to a posteriori methods.

In this method, CHMS frequency data were used as input variables. The PCA analysis was applied to reveal the presence of strong correlations, between the CHMS dietary variables. The scree plot, Kaiser's criterion (Newby and Tucker, 2004) and interpretation suggested the number of components to retain. To understand the contribution of the variables on each component, the factor loading score (specific cut-offs used are indicated in each Study 4 and 5) for each of the variables included in the components were obtained using the rotated component matrix. The varimax rotation method was used in this thesis to rotate the factors in order to obtain more interpretable and uncorrelated factors. The components or dietary patterns were named based on the food group variables characterizing them and the cut-off value for factor loadings (Panagiotakos et al., 2007).

4.3.4. Metabolic Syndrome Definition

The unified definition of MetS was applied to assess MetS prevalence amongst adults for study 4 and 5 (Alberti et al., 2009, Table 4.3). This criterion indicates that MetS is present when at least three of the aforementioned five components of MetS are present. Waist circumference was measured using the WHO in Cycle 1 and the National Health Institute protocols in Cycle 2. A study conducted on this survey data compared the two approaches, with results indicating a significant difference between the two (Patry-Parisien, Shields, & Bryan, 2012). However, Statistics Canada (2014a) has permitted combining waist circumference data of both different protocols with the condition of pointing out this limitation. In addition, the combined Cycles 1 and 2 data (WHO protocol) have been used to assess waist circumference among the adult Canadian population by other researchers (Clarke & Janssen, 2013). In this thesis, the ethnic classification of Alberti et al., (2009) was used for assigning the ethnic-specific waist circumferences. Moreover, the fasting blood glucose in Cycle 1 was analyzed from the blood plasma, while in Cycle 2 it was analyzed using blood serum. However, Statistics Canada argues that there is no significant difference between the two procedures and combined data may be used to analyze blood glucose levels (Statistics Canada, 2014a).

There is no unified definition for diagnosis of MetS among adolescents. Studies have either chosen to use the 2007 IDF consensus report or have subjectively assigned high-risk cut-offs (Zimmet et al., 2007). Choosing cut-offs based on the IDF adult criteria would be more appropriate and also reliable (Zimmet et al., 2007). Thus, in the present study, the latter criteria was used for adolescents.

Table 4. 3. A unified criterion for metabolic syndrome diagnosis among adults (Alberti et al., 2009).

Metabolic syndrome component	Cut-off
Abdominal obesity	Population and Ethnic-specific
Increased Triglyceride†	≥ 150 mg/dL (1.7 mmol/L)
Reduced high density lipoprotein†	< 40 mg/dL (1.0 mmol/L) in males; < 50 mg/dL (1.3 mmol/L) in females
Elevated blood pressure†	Systolic ≥130 and/or diastolic ≥85 mm Hg
Elevated fasting glucose†	≥5.6 mmol/L

* If at least three out of five components are present, metabolic syndrome is present in the individual.
†Drug treatment is an alternative indicator.

4.3.4.1. Diabetes

There are a number of individuals with known diabetes (individuals who know they have diabetes) in the MetS group (n=71 in Cycle 1) (Setayeshgar et al., 2012). The adherence of these individuals to a special diet will impact the relationship between MetS and diet. Therefore, people with diagnosed diabetes by a health professional were excluded from the MetS, 10-year ASCVD risk, and CAG analysis. Moreover, in Studies 2-5, the insulin-dependent individuals were removed (n= 93) to exclude type I diabetes and progressive type 2 diabetes.

4.3.5. Ten Year Atherosclerotic Cardiovascular Disease Risk Approach

This analysis was conducted on data collected from the adult population (ages 40-79 years). The 10-year risk of ASCVD was assessed using the ACC/AHA recommended risk assessment tool (Goff et al., 2013). The 10-year ASCVD risk for individuals aged 40 to 79 years was obtained using four sex-ethnic specific equations. These equations are obtained by using the sex-ethnic coefficients indicated in Tables A and B of the “2013 ACC/AHA Guideline on the Assessment of Cardiovascular Risk” document (Goff et al., 2013). Also, based on the sample size available only two categories of low and high risk were considered with 7.5 % risk of CVD in the next 10 years as a cut-off (i.e., risk < 7.5 % is low risk) (indicated in Figure 1 of Goff et al., 2013).

The following points should be considered in calculating the 10-year ASCVD risk using data from CHMS. First, in this study, all ethnicities are considered “White” except for the

“Black” ethnicity. However, the ACC/AHA recommends interpreting results with caution when this method is used for Hispanic Whites due to overestimation of this ethnic group’s risk by these equations (Goff et al., 2013). Second, In CHMS, questions regarding medication use are presented in both the household and MEC questionnaire. In the present study, the latter data were used that is based on the drug identification number (Joffres, Shields, Tremblay, Gorber, 2013). In addition, the CAG of adults (40 to 79 years) was determined in this study using D’Agostino et al. (2008) sex-specific cardiovascular age spreadsheets. The CAG of the Canadian adult population (40-79 years) was obtained by subtracting the chronological age from the cardiovascular age (Grover et al., 2007).

4.3.6. Analytical Approaches

The statistical analyses of Studies 2 to 5 are presented in detail in each Chapter separately.

The next chapter includes the assessment of the dietary intake of Canadians based on intake from the main food groups among Canadians 6-79 years and across different levels of socio-demographic factors.

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CHAPTER 5: Canadians Dietary Intake from 2007-2011 Across Different Socio-demographic/lifestyle Factors Using the Canadian Health Measures Survey Cycles 1&2

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Canadians Dietary Intake from 2007-2011 Across Different Socio-demographic/lifestyle Factors Using the Canadian Health Measures Survey Cycles 1&2

As an initial step in using the CHMS data from 2007-11 to address Objective 2 of this thesis, we investigate the dietary status of Canadians in terms of food group/item intakes. The present study provided an overview of the dietary intake of Canadians from the most recent data available in Canada.

5.1. Abstract

Nutrition is an important factor that impacts health, yet in Canada, there have been only a few surveys reflecting dietary intakes. The CHMS is a national survey that includes both food intake data as targeted questions and objective health measures. The aim of this study was to determine food group intakes reported in CHMS, Cycles 1 & 2 (2007-2011) and to report the items missing from the CHMS FFQ compared to Canadian Community Health Survey (CCHS) 2.2 (2004). The CHMS Cycles 1 & 2 included food questions for all food groups: Meat and Alternatives; Milk Products; Grains; Vegetables and Fruit; and beverages of Canadians (6-79 years, n=11,387). Further, Canadians' food intakes were assessed across socio-demographic characteristics. The CHMS dietary intake data from Vegetables and Fruit and from Milk Alternatives groups were almost completely based on food groups' food items of Health Canada. For the Grains and Meat and Alternatives groups the difference in intakes suggested CHMS data by FFQ was not complete compared to CCHS 2.2. However, patterns in food intakes with regards to age/sex and income showed similarities to the literature. Not all food groups measured in CHMS provide complete dietary intake data, yet CHMS food group intakes provide valuable information when it comes to evaluating dietary intake across different population groups.

5.2. Introduction

Research has determined the impact of nutrition on health among populations; however, in Canada, only a few national surveys have included a dietary intake section. The first national nutrition survey, "Nutrition Canada" conducted from 1970 to 1972, indicated that Canadians had some nutrient inadequacies from diet and clinical or biochemical deficiencies (e.g., serum folate) (Sabry, Campbell, Campbell, & Forbes, 1974). The second comprehensive national survey was conducted in 2004 as a part of the series of CCHS (Health Canada, 2007; Mathez, VanTongeren, & Schweitzer, 2013). This nutrition-focused survey was called CCHS 2.2 and included a repeated 24-hour dietary recall for collecting usual dietary intake data. These data showed low compliance of Canadians to the recommended intake of food groups (Garriguet, 2007).

The CHMS is a national survey that includes both food intake data and objective health measures. This survey is ongoing and has been running in bi-yearly cycles since 2007 (Mccord et al., 2014a). Researchers have started using the dietary intake data from CHMS to determine the association between dietary intake and disease (Setayeshgar, Whiting, & Vatanparast, 2012; Ye, Beach, Martin, & Senthilselvan, 2015). The dietary intake data, which are derived from targeted food frequency questions, have yet to be evaluated in terms of whether they provide comprehensive information on food intake to the health research community.

All dietary assessment methods have their strengths and limitations, which make them suitable for certain applications (Satija, Yu, Willett, & Hu, 2015). The FFQ represents usual intake data of a period of time using a finite list of questions regarding usual intake data. This tool is less expensive, more feasible and has less random within-person variation than other methods, thus is a common candidate for large survey data (Satija et al., 2015). However, this measurement tool is less accurate in estimating the nutrient composition of food and requires more cognitive effort resulting in higher measurement error compared to a 24-hour dietary recall (Subar et al., 2015). Although the latter tool is not as feasible as an FFQ, through its open-ended approach more details regarding the variety and quantity of food are collected (Satija et al., 2015).

The aim of this research, therefore, is to report food group intake data from the FFQ in CHMS combined Cycles 1 & 2 (2007-11). Further, the association of socio-demographic varibales with dietary intake data will be reported based on the CHMS data. We hypothesized that females have greater intakes of Vegetables and Fruit group and less intake of SSB. The intake of Vegetables and Fruit are greater for higher income and education level groups.

5.3. Subjects and Methods

5.3.1. Data Resource and Study Population

The CHMS is conducted by Statistics Canada in collaboration with Health Canada and the Public Health Agency of Canada (Mccord et al., 2014a). Cycles 1 (2007-09) and 2 (2009-11) included approximately 5,600 (aged six to 79 years) and 6,400 (aged three to 79 years) participants, respectively through a multistage sampling strategy (Statisitics Canada, 2013; Statistics Canada, 2011). The survey covers almost 96.3% of the target population, which are all individuals living in Canada within the ages of three to 79 years. Excluded are people living on reserve or in other Aboriginal settlements, full-time members of the Canadian Forces, institutionalized residents and people living in remote regions and regions with low population density (Mccord et al., 2014a, 2014b). The adjusted final national response rate was 55.5% for Cycle 2 and 53.5% for the combined Cycles 1 and 2 (Dodds, 2006; Mccord et al., 2014a, 2014b). The total number of respondents included in this study was 11,387 (6-79y) for combined Cycles 1 and 2 data and 6,197 (4-79 years) using Cycle 2 data, which after administrating the survey weights in the analysis for these respondents, they were representative of 29,625,300 and 30,680,029 of the Canadian population, respectively.

5.3.2. Dietary Assessment

The data from CHMS Cycles 1 and 2 can be combined using Statistics Canada's "Instructions for combining cycle 1 and cycle 2 data" document (Statistics Canada, 2010a). Thus, for this study combined CHMS Cycles 1 and 2 data were used to compile the average daily consumption of food group intake (times/day) of Canadians (6-79 years) from targeted food frequency questions (indicated in Table 4.2). These questions were grouped into six categories of Meat consumption (eight questions); Milk and dairy product consumption (five questions); Grains, fruits and vegetables (13 questions); Dietary fat consumption (two questions); Water and soft drink consumption (10 questions); and Salt consumption (three questions). We included 32 questions in this study (additional details of the FFQ are included in 4.4.4 (Statistics Canada, 2014).

The CHMS FFQ has been developed with the aim of complementing physical and laboratory measurements. For example, the "Dietary fat consumption" questions are related to the cardiovascular health component of CHMS. The serving size was not reported in the FFQ data.

We named the food groups in this study based on Canada's Food Guide to Healthy Eating (1992) (Health Canada, 2007) to be descriptively comparable with (Garriguet, 2007). For the group of Meat and Alternatives, only CHMS Cycle 2 (4-79y) data was used due to the inconsistency between fish and shellfish data from the two cycles of CHMS.

5.3.3. Dietary Intake by Socio-demographic Characteristics

Mean intakes by different socio-demographic and lifestyle characteristics were evaluated. The socio-economic factors including age, sex, income, education, and physical activity were classified into their corresponding categories (e.g., two categories of male and female for sex) and by two age groups of 6-18 and 19-79 years. The age-sex specific categories were developed based on categories used by Garriguet (2007), 6-8 y, 9-13y, 14-18y, 19-30 ye, 31-50y, 51-69, 70-79y except for the first and last age categories, which were 6-8 and 71-79 years for this study. Income was measured based on CHMS data of total household income, before taxes and deductions from sources since one year before the interview day, and considering the number of household members (Statistics Canada, 2010b). Education was categorized according to the CHMS household questionnaire classifications into four levels. Physical activity was indicated as the Physical Activity Index with the following categories in CHMS dataset (Statistics Canada, 2010b) : active, moderately active and inactive. Finally, ethnicity was categorised as White and non-White.

5.3.4. Data Analysis

Statistics Canada allows combining the first two cycles with the exception of a few variables that were not used in this research (Statistics Canada, 2010b). To ensure that data from the two consecutive CHMS Cycles 1 and 2 are representative, weighting and bootstrapping were applied and combining data from these cycles was done based on Statistics Canada's instructions (Mccord et al., 2014a; Statistics Canada, 2010a). The intake of food groups/beverages was determined across demographic and socioeconomic factors as mean ± standard error. The mean estimate 95% confidence interval (CI) was used to evaluate significant differences between different levels. "No Overlap" existing between CI's was considered as a statistically significant result (Colegrave & Ruxton, 2003). IBM SPSS Statistics for Windows (v20, IBM Corp., Armonk, U.S.) was used for data processing, cleaning, and manipulation. STATA/SE (v11, StataCorp LP., College Station, U.S.) was used for statistical analysis.

5.4. Results

5.4.1. Food Group Intake Based on Demographics

Based on the CHMS data sets used in this analysis Canadians reported having 1.62, 1.64, 4.33 , 2.17, 0.47, 0.47, 0.14 and 0.7 serving/day from Meat and Alternatives; Milk Products; Vegetables and Fruit; Grain Products; dietary fat; SSB; diet drinks; and fruit and vegetable juice, respectively (Table 5.1 and 5.2).

Age differences in intake were apparent in CHMS (Table 5.3). Adults had significantly fewer serving intakes from SSB and fruit and vegetable juice (0.42 and 0.66 serving/day, respectively, $p < 0.05$) (Table 5.2) compared to children and adolescents (0.70 and 0.89 serving/day, respectively, $p < 0.05$). However, adults had more intakes from diet drinks (0.16 serving/day) compared to children and adolescents (0.05 serving/day, $p < 0.05$).

The dietary intake from CHMS among Canadians was different across socio-demographic characteristics including age, sex, education, income, ethnicity, and physical activity. Of all types of food groups examined, Canadian females (6-79 years) had greater intakes from the Vegetables and Fruit group and less from Grain Products and SSB group compared to Canadian males.

Based on CHMS 2007-11, within the age-sex groups, there were expected differences for Grain Products intake based on body size or energy requirements. For example, females in the 14-18y age group have reported less intake from Grain Products (2.18 serving/day) compared to males in the same age group (2.54 serving/day, $p < 0.05$). Further, the males in the 19-30y age group (2.42 serving/day) have reported more Grain Products intake compared to males in the 31-50y age group (2.13 serving/day, $p < 0.05$).

5.4.2. Food Group Intake Based on Income and Education

Based on CHMS data from Cycles 1 and 2, the intakes of Canadians were different across income and education levels for some food groups. Regarding income, within the 6-18y and the 19-79y age groups, the middle-income group (4.20 and 3.99 serving/day, respectively) had less intake from the Vegetables and Fruit group compared to the high-income group (4.60 and 4.44 serving/day, respectively, $p < 0.05$). Furthermore, according to data reported in CHMS, in the age range of 6-18y, the low-and middle-income group had higher SSB intake (1.25 and 0.90 serving/day respectively) compared to the high-income group (0.59 serving/day, $p < 0.05$).

Finally, the intake of Milk and Alternatives (2.54 vs 2.24 serving/day for ages 6-18y; 1.53 vs 1.23 serving/day for ages 19-79y); Vegetables and Fruits group (3.68 vs 3.28 serving/day for ages 6-18y; 3.70 vs 3.46 serving/day for ages 19-79y); and diet soft drinks (0.06 vs 0.03 serving/day for ages 6-18y and 0.69 vs 0.53 serving/day for ages 19-79y) were greater for the White group compared to non-White group.

Canadians aged 19-79y, with less than secondary and secondary level of education, had fewer intakes from the Vegetables and Fruit group (3.89 and 4.01 serving/day, respectively) and higher SSB intake (0.55 and 0.56 serving/day, respectively) compared to the group with post-secondary level of education (4.50 serving/day for Vegetables and Fruits intake and 0.32 serving/day for the SSB intake, $p<0.05$).

5.4.3. Food Group Intake Based on Physical Activity

The active group aged 6-18y had a higher intake from the Vegetables and Fruit and Milk Products (4.44 and 2.37 serving/day, respectively) compared to the non-active group in this age range (3.86 and 1.83 serving/day, respectively, $p<0.05$). Similarly, the active group aged 19-79y had more intake from Vegetables and Fruit; Milk Products; and fruit and vegetable juice (4.81, 1.63 and 0.72 serving/day, respectively) compared to the inactive group (3.93, 1.36 and 0.61 serving/day, respectively, $p<0.05$) within the same age group.

Table 5. 1. Mean intake and 95% confidence interval of food intake (serving/day) of Canadians 6-79y, by age-sex and income from the CHMS combined Cycles 1 and 2 (n= 11,387, representative of population size: 29,625,300) (for Meat and Alternatives only Cycle 2 (ages 4-79y) was used, n= 6,197 representative of population of 30,680,029).

	Meat and Alternatives Mean (SE) (95% CI)	**Milk Products** Mean (SE) (95% CI)	**Vegetable and fruits** Mean (SE) (95% CI)	**Grains** Mean (SE) (95% CI)
Total	1.62 (0.03) (1.55-1.7)	1.64 (0.03) (1.57-1.71)	4.33(0.05) (4.23-4.42)	2.17 (0.02) (2.12-2.21)
Age-sex				
6-8 (M,F)	1.38 (0.033) (1.30-1.45)	3.01 (0.06) (2.88-3.14)	4.65 (0.10) (4.43-4.86)	2.50 (0.05) (2.40-2.60)
9-13 (M)	1.34 (0.05) (1.24-1.44)	2.68 (0.07) (2.53-2.83)*’†	4.37 (0.12) (4.13-4.61)	2.51 (0.05) (2.4-2.61)
9-13 (F)	1.30 (0.06) (1.17-1.42)	2.38 (0.06) (2.25-2.51)†	4.70 (0.12) (4.44-4.95)	2.41 (0.05) (2.31-2.52)
14-18 (M)	1.51 (0.07) (1.36-1.66)	2.4 (0.1) (2.2-2.61)*	3.99(0.12) (3.76-4.23)	2.54 (0.07) (2.32-2.6)*
14-18 (F)	1.33 (0.08) (1.17-1.50)	1.87 (0.09) (1.69-2.05)†	4.38(0.11) (4.15-4.61)	2.18 (0.06) (2.06-2.29)†
19-30 (M)	1.92 (0.13) (1.65-2.20)*	1.67 (0.11) (1.44-1.90)†	4.08(0.18) (3.71-4.45)	2.42 (0.08) (2.26-2.58)
19-30 (F)	1.44 (0.06) (1.30-1.58)	1.71 (0.07) (1.56-1.86)	4.30(0.14) (4.02-4.58)	2.19 (0.05) (2.09-2.30)
31-50 (M)	1.77 (0.07) (1.61-1.92)	1.32 (0.04) (1.24-1.41)†’*	3.87(0.08) (3.70-4.04)*	2.13 (0.04) (2.04-2.22)†
31-50 (F)	1.67 (0.09) (1.48-1.86)	1.55 (0.06) (1.42-1.68)	4.63(0.10) (4.43-4.84)	2.06 (0.05) (1.95-2.17)
51-69 (M)	1.70 (0.05) (1.58-1.80)	1.20 (0.05) (1.11-1.29)*	4.13(0.10) (3.93-4.33)*	2.07 (0.05) (1.97-2.18)
51-69 (F)	1.63 (0.07) (1.49-1.78)	1.50 (0.05) (1.40-1.61)	4.59(0.11) (4.37-4.81)	1.96 (0.04) (1.87-2.04)
70-79 (M)	1.51 (0.05) (1.40-1.62)	1.45 (0.08) (1.28-1.62)	4.50 (0.09) (4.32-4.69)	2.19 (0.07) (2.05-2.33)
70-79 (F)	1.57 (0.08) (1.39-1.74)	1.62 (0.11) (1.39-1.84)	5.05(0.23) (4.57-5.53)†	2.06 (0.09) (1.87-2.24)
Income (6-18y)				
Low	1.20 (0.18) (0.82-1.59)	2.54 (0.19) (2.14-2.94)	4.63 (0.65) (3.30-5.97)	2.34 (0.32) (1.69-2.99)
Lower Middle	1.41 (0.09) (1.21-1.61)	2.25 (0.15) (1.94-2.56)	4.12 (0.24) (3.62-4.62)	2.53 (0.07) (2.39-2.67)

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Middle	1.47 (0.04) (1.39-1.56)	2.47 (0.08) (2.30-2.64)	4.20 (0.12) (3.94-4.45)*	2.52 (0.05) (2.41-2.62)
Upper Middle	1.36 (0.05) (1.25-1.48)	2.32 (0.06) (2.20-2.46)	4.25 (0.14) (3.97-4.53)	2.37 (0.05) (2.27-2.47)
High	1.34 (0.05) (1.25-1.44)	2.55 (0.07) (2.41-2.69)	4.60 (0.07) (4.45-4.74)	2.38 (0.04) (2.31-2.46)
Income (19-79y)				
Low	1.36 (0.15) (1.04-1.69)	1.49 (0.20) (1.08-1.90)	4.02 (0.34) (3.32-4.72)	2.09 (0.17) (1.74-2.44)
Lower Middle	1.61 (0.09) (1.41-1.80)	1.49 (0.17) (1.14-1.84)	3.98 (0.25) (3.47-4.49)	2.39 (0.14) (2.10-2.67)
Middle	1.66 (0.11) (1.42-1.90)	1.44 (0.09) (1.27-1.62)	3.99 (0.12) (3.75-4.23)*	2.20 (0.04) (2.11-2.29)
Upper Middle	1.61 (0.06) (1.48-1.74)	1.46 (0.05) (1.37-1.55)	4.31 (0.08) (4.14-4.48)	2.12 (0.04) (2.03-2.18)
High	1.74 (0.04) (1.66-1.83)	1.49 (0.03) (1.42-1.56)	4.44 (0.07) (4.28-4.59)	2.08 (0.03) (2.02-2.14)

Canadian

Measures Survey combined Cycles 1 and 2 (2007-11); CI, Confidence interval; M, males; F, females SE, standard error; y, years.

* Significantly different intake of food group from females of the same age group for the age-sex variable or from a reference group for income variable ($p < 0.05$). For the variable of income, asterisk symbol indicated significantly different intake of food group from the "High" level of income.

† Significantly different intake from food group from similar sex within the previous age group ($p < 0.05$).

Table 5. 2. Mean intake and 95% confidence interval of dietary fat and beverages (times/day) of Canadians 6-79y, by socio-demographic characteristics, Canadian Health Measures Survey Cycles 1 and 2 (number of observations= 11,387, representative of population size: 29,625,300).

	Dietary fat	Sugar-sweetened beverages	Diet-Drink	Fruit and vegetable juice	Beverages (SSB, diet-drinks, fruit and vegetables juice, alcohol intake and water)
	Mean (95% CI)	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**
Total (6-79y)	0.47 (0.45-0.5)	0.47 (0.43-0.51)	0.14 (0.12-0.16)	0.7 (0.66-0.73)	5.73 (5.59-5.87)
Age					
6-18y	0.54 (0.51-0.58)	0.7 (0.65-0.76)	0.05 (0.04-0.06)	0.89 (0.84-0.94)	5.11 (4.96-5.28)
19-79	0.46 (0.43-0.49)	0.42 (0.37-0.47)	0.16 (0.14-0.18)	0.66 (0.62-0.69)	5.85 (5.7-6)
M	0.48 (0.45-0.51)	0.59 (0.52-0.66)*	0.14 (0.12-0.16)	0.73 (0.69-0.78)	6.03 (5.81-6.26)*
F	0.47 (0.44-0.49)	0.35 (0.32-0.39)	0.14 (0.11-0.16)	0.66 (0.62-0.7)	5.42 (5.28-5.57)
Age groups by sex					
6-8y	0.47 (0.40-0.54)	0.47 (0.42-0.52)	0.03 (0.01-0.04)	0.95 (0.84-1.04)	4.87 (4.6-5.13)

9-13y					
M	0.5 (0.45-0.54)	0.6 (0.62-0.77) †	0.04 (0.03-0.05)	0.94 (0.85-1.02)	4.87 (4.64-5.09)
F	0.56 (0.49-0.63)	0.63 (0.53-0.73) †	0.04 (0.02-0.06)	0.93 (0.82-1.04)	4.68 (4.42-4.95)
14-18y					
M	0.61 (0.56-0.66)†	1.04 (0.90-1.17) †	0.07 (0.4-0.11)	0.84 (0.74-0.95)	5.9 (5.51-6.29) †
F	0.58 (0.51-0.64)	0.67 (0.57-0.77)*	0.09 (0.06-0.12)	0.82 (0.69-0.95)	5.21 (4.85-5.58)
19-30y					
M	0.56 (0.46-0.67)	0.93 (0.65-1.21)	0.09 (0.06-0.13)	0.8 (0.67-0.93)	7.14 (6.37-7.91) †
F	0.5 (0.43-0.56)	0.53 (0.43-0.64)*	0.11 (0.07-0.15)	0.67 (0.58-0.77)	5.61 (5.24-6.00)*
31-50y					
M	0.46 (0.42-0.5)	0.51 (0.45-0.57) †	0.16 (0.12-0.19)	0.64 (0.58-0.71)	6.18 (5.88-6.48)
F	0.47 (0.42-0.51)	0.29 (0.23-0.34)*†	0.18 (0.14-0.22)	0.63 (0.56-0.69)	5.8 (5.57-6.03)
51-70y					
M	0.42 (0.37-0.47)	0.39 (0.24-0.53)	0.22 (0.15-0.29)	0.7 (0.60-0.81)	5.73 (5.32-6.14)
F	0.41 (0.37-0.45)	0.19 (0.12-0.25)	0.15 (0.11-0.19)	0.56 (0.5-0.62)	5.21 (5.05-5.36)†
71-79y					
M	0.4 (0.35-0.45)	0.13 (0.08-0.18)†	0.14 (0.1-0.18)	0.64 (0.55-0.73)	4.7 (4.36-5.04)†
F	0.4	0.18	0.12	0.69	5.1

† Significantly different intake of food group from similar sex within the previous age group ($p < 0.05$).

	(0.31-0.48)	(0.09-0.28)	(0.04-0.17)	(0.61-0.77)	(4.71-5.49)
Income 6-18y					
Low	0.63 (0.32-0.95)	1.25 (0.89-1.61)*	0.14 (0-0.36)	0.74 (0.52-0.96)	4.74 (3.93-5.56)
Lower Middle	0.57 (0.48-0.66)	0.83 (0.45-1.2)	0.05 (0-0.11)	1.01 (0.72-1.31)	6.19 (5.27-7.12)*
Middle	0.5 (0.42-0.57)	0.9 (0.78-1.02)*	0.05 (0.03-0.06)	0.84 (0.73-0.94)	5.23 (4.83-5.63)
Upper Middle	0.53 (0.48-0.57)	0.74 (0.63-0.85)	0.05 (0.04-0.07)	0.92 (0.83-1.01)	5.25 (5-5.49)
High	0.57 (0.51-0.62)	0.59 (0.53-0.65)’	0.06 (0.04-0.07)	0.89 (0.83-0.95)	4.9 (4.7-5.12)
Income 19-79y					
Low	0.43 (0.33-0.54)	0.45 (0.18-0.72)	0.13 (0.02-0.25)	0.52 (0.4-0.65)	6.17 (5.39-6.96)
Lower Middle	0.41 (0.31-0.52)	0.5 (0.37-0.63)	0.23 (0.0-0.47)	0.75 (0.54-0.96)	5.78 (5.07-6.49)
Middle	0.43 (0.39-0.48)	0.42 (0.36-0.48)	0.14 (0.1-0.17)	0.6 (0.53-0.67)	5.62 (5.26-5.99)
Upper Middle	0.46 (0.43-0.5)	0.46 (0.4-0.53)	0.14 (0.11-0.17)	0.66 (0.61-0.72)	5.82 (5.61-6.02)
High	0.47 (0.44-0.5)	0.39 (0.32-0.47)	0.17 (0.14-0.19)	0.67 (0.62-0.71)	5.93 (5.73-6.13)

CHMS, Canadian Health Measures Survey combined Cycles 1 and 2 (2007-11); CI, confidence interval; M, males; F, females; y, years.
* Significantly different intake from the 19-79 years age group for the “age groups by sex “variable. Significantly different intake of food group from females of the same age group for the “Age-sex” variable; significantly different intake of food group from “High” level of “Income” group ($p < 0.05$).

Table 5. 3. Canadians' food group intake reported from the Canadian Health Measures Survey (2007-2011).

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Food Group	Children and adolescents * Mean [SE] (95% CI) (2007-11, 6-18y*, n= 4,032)	Adults Mean [SE[1]] (95% CI) (2007-11, 19-79y, n= 7355)
Meat and Alternatives	1.37 [0.03] (1.32-1.43)	1.68 [0.04] (1.60-1.77)
Milk Products	2.46 [0.05] (2.37-2.55)	1.47 [0.03] (1.40-1.54)
Vegetables and fruits	4.41 [0.06] (4.29-4.53)	4.33 [0.05] (4.23-4.42)
Grain Products	2.41 [0.03] (2.35-2.47)	2.12 [0.03] (2.07-2.17)

Canadian Health Measures Survey combined Cycles 1 and 2 data; CI, confidence interval; n, sample size; SE, standard error; y, years.

*Children and adolescents age range for Canadian Health Measures Survey is 6-18 years for all food groups except for meat and alternatives, which is 4-18 years.

5. 5. Discussion

This study extracted and reported dietary intake data from CHMS cycles 1 and 2, a recent nationally representative health survey that included a dietary measurement. These results demonstrate that of all the types of food groups examined from CHMS data, Canadian woman (6-79 years) had more intakes from Vegetables and Fruit and less from Grain Products and SSB compared to Canadian men. As well, the intake from the Vegetables and Fruit group varies across different socio-demographic and lifestyle factors including age, sex, education, income, and physical activity.

We defined for CHMS, the Vegetables and Fruit group based on Canada's Food Guide 1992 (Health Canada, 2007). The impact of this food group in preventing chronic diseases such as CVD, diabetes, and cancer has been reported in several studies (Fu et al., 2016; Ness & Powles, 1997; Wang et al., 2014). As a result, dietary guidelines have indicated that this food group is one of the essential food groups that should be consumed abundantly on a daily basis, and one, which should be monitored in the population. Based on the results of this study, Canadians' intake of the Vegetables and Fruit group reported in CHMS (2007-11) was similar to what was observed in CCHS 2.2 (Garriguet, 2007). Moreover, the FFQ in CHMS has covered all items in the Health Canada Vegetables and Fruit group. This may indicate that the quantity of Vegetables and Fruit intake group was adequately covered by the CHMS FFQ food list. However, the intake from the different components of this food group in unclear.

The CHMS FFQ did not include a few items from the Milk Products group indicated in Table 3. The analysis of this study also indicates Canadians' intake from Milk Products as reported in CHMS (2007-11) is similar to that from CCHS 2.2 (Garriguet, 2007). This group is an important source of calcium and therefore accurate assessment of it is important from monitoring. However, a large difference was observed for intakes from Grains Product group and from Meat and Alternatives group between the two surveys. The intake from Grains group was much lower in CHMS (2007-11) compared to CCHS 2.2 (Garriguet, 2007). This is probably due to not including the following grain products in the CHMS FFQ food list, which are among the commonly consumed grain products in Canada (Health Canada, 2007): quinoa, bulgur, oatmeal, cornmeal, barley, buckwheat, rye, amaranth, millet, sorghum, triticale, couscous, pretzels, popcorn, crackers, pancakes and waffles (Health Canada, 2007; Vatanparast et al., 2017). Further, the CHMS FFQ does not cover intake from aggregated foods such as pizza, which are generally not easily captured by the FFQ method (Thompson & Subar, 2017). It is noteworthy that in CHMS, whole wheat, and white grain products are not distinguished except for bread (e.g., brown rice vs. white rice) (Table 5.4).

Red meat, poultry, pulses and nuts, eggs and fish have been the most consumed Meat and Alternatives products in Canada, respectively. However, the CHMS FFQ does not include questions regarding the intake from poultry, game birds, game meat, different beans, pulses, legumes and foods such as hummus and tofu (Statistics Canada, 2014; (Health Canada, 2007). In addition, other meats such as goat, rabbit, bison/buffalo, and veal are not included in the CHMS FFQ food list, which are not as common as the former foods listed (Health Canada, 2007) (Table 5.3). However, CHMS FFQ has covered red and processed meats; fish and shellfish; and egg intake, which are important food sub-groups considered in investigating the association between different health outcomes and intake from these foods (Babio et al., 2012; Micha, Wallace, & Mozaffarian, 2010; Morris MC Manson JE, n.d.; Rouhani, Salehi-Abargouei, Surkan, & Azadbakht, 2014).

Table 5. 4. The list of missing foods in the Canadian Health Measures Survey food frequency questionnaire (based on the intake of food in Canada and Health Canada food list).

Food groups*	Missing foods in the CHMS dietary questionnaire
Meat and Alternatives group	- Pulses/legumes (except dried beans) and some foods made of them such as hummus and tofu - Poultry (such as chicken, turkey, and duck) and game birds - Game meat (such as deer, moose, caribou, elk) - Other meats such as deli meat, goat, rabbit, bison/buffalo, and veal.
Milk Products group	-Block/processed cheese (such as cheddar, Mozzarella, Swiss, feta) -Other type of cheese such as cottage, quark, goat cheese and paneer -Buttermilk -Kefir -Pudding/custard -Yoghurt drink
Grains Products group	-Brown pasta and white pasta -Brown rice and white rice -Crackers, popcorn, pancakes, pretzels, and waffles -Oatmeal, quinoa, bulgur, couscous, cornmeal, buckwheat, barley, rye, amaranth, millet, sorghum, triticale or any other grains -Aggregated foods such as pizza
Vegetables and Fruit group	-
Dietary fat	-Butter -Margarine -Unsaturated vegetable oils such as canola, corn, flaxseed, olive, peanut, soybean and sunflower
Beverages	-Coffee -Tea

* Food groups are named based on the 1992 Canada's Food Guide and reported in Garriguet (2007).

Based on the results of this study, the intake from the Meat and Alternatives group was lower in CHMS (2007-11) compared to Garriguet (2007).

According to Statistics Canada, the initial aim of the CHMS dietary intake data FFQ was to complement physical and lab measures. For example, the dietary fat intake questions are intended to provide useful information for the cardiovascular health panel. Thus, despite the targeted CHMS dietary intake questionnaire, this research indicates that questions from Vegetables and Fruit and the Milk Products intake mostly capture the intake from these food groups. However, the Meat and Alternatives and the Grain Products groups require the addition of a number of foods that have been indicated in Table 5.4, in order to represent intake from these food groups for the Canadian population.

Canadian women had more intakes from the Vegetables and Fruit group compared to men. Similarly, Garriguet (2007) showed women of ages 19-30 years and 51 years and older had higher intakes from the Vegetables and Fruit group compared to males of the same age categories. As well, data from CCHS 2011 and 2012 using the Vegetables and Fruit FFQ indicated that Canadian women were more likely to have five or more servings per day intake from Vegetables and Fruit group compared to males (2007). This difference observed between the sexes is expected, given the higher nutritional knowledge among women compared to men (Baker & Wardle, 2003).

Comparing the intake from the Grain Products across age-sex populations indicated patterns in energy intake in CHMS data. For example, overall males (2.23 serving/day) have greater intakes from the Grains Products compared to females (2.10 serving/day, $p<0.05$), which was also observed in CCHS 2.2 (Garriguet, 2007) . As well, younger males aged 19-30 years (2.42 serving/day) have greater intakes from this food group compared to older males aged 31-50 years (2.13 serving/day, $p<0.05$). Should grains be considered as a surrogate for energy intake, the pattern in energy intake across age-sex groups in CHMS (2007-11) was also observed in CCHS 2.2 (2004) (Garriguet, 2007). Regarding Milk Products, based on CHMS dietary data, the intake was progressively lower in younger age groups than older age groups in Canada. Further, children and adolescents have greater amounts of intake from Milk Products compared to adults, similar to the pattern observed in 2004 using CCHS 2.2.

Our study based on CHMS data reported the food group intake of Canadian from the Vegetables and Fruit group by physical activity status. The CHMS data showed that active Canadians had more intakes from this food group compared to inactive Canadians. This is consistent with what was observed in a national study conducted in 2002, where active Canadians had higher intakes from the vegetables and fruits group compared to inactive Canadians (Statistics Canada, 2009). They concluded that a higher intake from this food group is indicative of compliance to other healthy behaviours such as being physically active and non-smoker (Statistics Canada, 2009). The results from this research are supported by results from two other national studies, which indicate that socio-demographic and lifestyle factors impact the consumption rate of Vegetables and Fruit among Canadians (Diane Riediger, Natalie; Shooshtari

Shahin, 2007). In addition, active Canadians have greater intakes from Milk and Alternatives compared to inactive Canadians. This may be due to choosing an overall healthier lifestyle among this group of population (Weaver, 2000).

There are limitations of this study. The dietary intake data in CHMS was collected through a semi-quantitative questionnaire, in which the frequency of intake was recorded rather than the quantity. In the analysis for CHMS, the youngest age-sex group included 6-8 year olds, (missing ages 4 and 5 years) and the oldest group included 71-79 year olds (missing ages above 79 years). The missing age groups are a small proportion of the overall age groups covered in CHMS. Moreover, the FFQ in CHMS does not cover all type of foods; therefore, this limitation should be considered while interpreting results. It may be possible for Statistics Canada to add the missing food items to the CHMS FFQ, as CHMS is an ongoing survey.

5.6. Conclusion

The CHMS is an ongoing Canadian survey that employs an FFQ for dietary assessment, which may cause confusion by health researchers as to use dietary intake data. The reported Meat and Alternatives and Grain Products intake data should be used with caution as key foods in these groups were omitted from the FFQ. The CHMS dietary intake data provides valuable information when it comes to evaluating the dietary intake across different population groups. Furthermore, a list of omitted foods from the CHMS FFQ has been presented in this study, which could be useful to both researchers and Statistics Canada.

In this Chapter, we determined the dietary intake of Canadians across different levels of socio-demographic and lifestyle factors (Objective 2). We found that CHMS FFQ provides valuable information and placing this data beside health-related objective measures provides a unique opportunity for researchers. Before moving on to determining the MetS prevalence and 10 year CVD risk of Canadians and their association with diet, we wanted to determine whether individuals diagnosed diabetes modify their diet based on recommendations provided by health professionals and knowing their disease status. If they modify their diet, then these people should be excluded from the study of assessing the association between Met and dietary patterns. Thus, in Chapter 6, we have investigated the status of diabetes among Canadians and assessed the intake of individuals with diagnosed diabetes by a health professional compared to individuals with no diagnosed diabetes.

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CHAPTER 6: The Prevalence of Type 2 Diabetes Among Canadian Adults and Association with Their Socio-demographic Factors and Dietary Habits Using Nationally Representative Canadians Health Measures Survey Cycle 1 & 2

6.1. Abstract

Patients with diagnosed diabetes receive recommendations by their healthcare providers about lifestyle modification, particularly diet. The aim of this study is to determine the prevalence of type 2 diagnosed diabetes, undetected (undiagnosed) type 2 diabetes and pre-diabetes among Canadian adults, and to evaluate whether individuals with diagnosed diabetes have different dietary intakes compared to the other groups. We used nationally representative data from CHMS Cycles 1 and 2 (n=6,807, representing estimated population of 23,022,890 Canadians 20-79y). We evaluated the prevalence of diagnosed diabetes, undetected diabetes and pre-diabetes and their distribution across socio-demographic and lifestyle factors. The intake from different food/food groups was compared between the group with diagnosed type 2 diabetes and the rest of the population. Among Canadians 20-79 years of age, 12.4% had pre-diabetes, and 7.5% had diabetes. Among all diabetes cases, 37.3% were undiagnosed. All three diabetic categories were more prevalent among older age groups compared to younger age groups. Diagnosed diabetes and pre-diabetes were more prevalent among less educated individuals compared to the higher educated ones. Diagnosed diabetes was more common among individuals with lower-middle income level compared to the highest income. Diagnosed diabetes individuals had fewer intakes from juice and ice-cream and more intake from potatoes and diet soft drinks compared to other groups. Many Canadian adults were unaware of their diabetes status; those who were aware had lower intakes of sugar-containing foods. In evaluating the association between dietary intake and risk of chronic diseases at the population level, diagnosed diabetes cases should be evaluated separately.

6.2. Introduction

The prevalence of type 2 diabetes has been rising in Canada and throughout the world (Ogurtsova et al., 2017) . Patients with diabetes have a two to four times higher risk of CVD death compared to other individuals (Cheng, 2013). In 2009, 2.4 million Canadians were diagnosed with diabetes. The prevalence of diabetes is estimated to increase by nearly 50% in Canada from 2015 until 2025 (Canadian Diabetese Association, 2010). This high number contributes to not only high burden on the person with diabetes but also a high burden on the Canadian healthcare system. Type 2 diabetes mainly remains asymptomatic for months to years before diagnoses, leading to initiation of microvascular complications (Leiter et al., 2011). Thus, the early diagnoses of the disease will provide benefits for controlling and preventing further complications.

One main factor, which may contribute to a lower risk of diabetes and also a controlling impact on this disease, is to practice an overall healthy diet (Fitzgerald, Damio, Segura-Perez, & Perez-Escamilla, 2008). High intakes of SSB, red or processed meat, refined grains, sweets, and snack have been shown to increase the risk of diabetes in individuals (Fitzgerald et al., 2008). Further, advocacy organizations have provided relevant information on dietary practices in their diabetes clinical guidelines, which are available to healthcare providers and patients (Punthakee, Goldenberg, & Katz, 2018). This information can assist in controlling diabetes in affected individuals.

Fasting plasma glucose, 2-hour oral glucose tolerance test (OGTT) and, recently, HbA1c, are used as diagnostic tests for diabetes (Punthakee et al., 2018). The HbA1C test is especially useful in research using large survey data compared to the two other methods that are less feasible due to time restrictions. The CHMS provides levels of HbA1C in addition to other objective health measures as well as food intake data using an FFQ. This survey has been ongoing in bi-yearly cycles since 2007 (Statistics Canada, 2014). In the present study, the CHMS data are used to determine the prevalence of diagnosed type 2 diabetes, undetected (the person has diabetes but is not aware of his/her disease status due to not being diagnosed) type 2 diabetes and pre-diabetes (term used based on Diabetes Canada 2018 Guidelines (Punthakee et al., 2018) for Canadian adults (20-79y) using the objective measure of HbA1C levels. Further, we determined whether individuals with diagnosed diabetes have different usual dietary intakes compared to other individuals. We hypothesized that diagnosed diabetes, undetected diabetes and prediabetes are more prevalent among groups with lower socio-demographic and lifestyle levels including income, physical activity, and education.

6.3. Subjects and Methods

6.3.1. Data Resource and Study Population

The ongoing nationally representative health survey CHMS was initiated by Statistics Canada in collaboration with Health Canada and the Public Health Agency of Canada (Statistics Canada, 2011, 2014), focusing on diseases and health, environmental factors, lifestyle, and social conditions. For Cycles 1 and 2, there was initially an interview held at the household, which collected demographics and thorough health information. A few days after the household interview, the participant visited the MEC for a second interview and the physical and laboratory sampling process. Cycle 1 of this survey was conducted from 2007 to 2009 and included approximately 5,600 participants aged 6-79 years; Cycle 2 ran from 2009 to 2011, and included approximately 6,400 participants aged 3-79 years (Statistics Canada, 2014) . The CHMS was estimated to include 96.3% of the target population. Those living on reserves/remote communities or in other Aboriginal settlements, institutionalized residents, and Canadian Forces full-time members were excluded from this survey (Statistics Canada, 2011, 2014). The ethics approval of this survey was obtained from the Health Canada's Research Ethics Board (Statistics Canada, 2011, 2014).

The sampling procedure in CHMS was multistage, including the sampling of collection sites (geographical unit), dwellings and person (Statistics Canada, 2014). Two main questionnaires, including one at the household and one at the clinic, were used to collect information. The dietary assessment was done through a semi-quantitative FFQ (details indicated in Section 4.3.3 of this thesis) (Statistics Canada, 2011, 2014). The response rate for the combined Cycles 1 and 2 was 53.5% (Statistics Canada, 2014). For the present study, we used the combined Cycles 1 and 2 data for non-pregnant individuals 20-79 years of age. The total number of respondents included in this study was 6,807, which were representative of 23,022,890 Canadians aged 20-79y.

6.3.2. Diabetes Classification

The categorization of type 2 diabetes status was based on two types of data available in the CHMS data sets: the diabetes diagnosis of the individual by health professionals (yes/no), and the HbA1c lab results (Table 6.1). The HbA1c level represents chronic hyperglycemia as it indicates the average plasma glucose of over the past eight to 12 weeks (World Health

Organization, 2011). In using these two criteria, three categories of individuals were formed : 1) individuals with diagnosed diabetes that had been confirmed by health professionals, 2) individuals with no diagnosis of diabetes but having HbA1c level in the range of diabetes (≥ 6.5%), called undetected diabetes in this study, and 3) individuals with pre-diabetes who had not been diagnosed with diabetes by a health professional and their HbA1c was between 6.0 and 6.49% (Punthakee et al., 2018) inclusive. In the present study, those individuals who had been diagnosed with type 1 diabetes or gestational diabetes were removed.

Table 6.1. Categorizing individuals based on their diabetes status using two variables available in the Canadian Health Measures Survey Cycles 1 and 2[†].

	Diagnosed by a health professional	Glycated hemoglobin A1c (HbA1C)[*]
No diabetes	No	< 6.0%
Pre-diabetes	No	6.0 ≤ HbA1C < 6.5
Undetected diabetes	No	≥ 6.5%
Diagnosed diabetes	Yes	Not applicable

[*] From Canadian Diabetes Association, 2010
[†] HbA1C, Hemoglobin A1C

6.3.3. Dietary Assessment

An FFQ was used to collect data regarding the usual intake of different food items (n=32) per day, week, month and year (Table 4.2) (Statistics Canada, 2011, 2014). We compiled the average daily consumption of food and food group intake, recorded as serving times per day, of Canadians (20-79 years) from the targeted food frequency questions (Statistics Canada, 2011, 2014). These food questions were written to determine the intake frequency of the following food groups: meat; fish and shellfish; milk and dairy products; grains; fruits and vegetables; dietary fat; salt; and water and soft drink consumption (fish and shellfish, salt and water intake data were not used in this study).

6.3.4. Socio-demographic and Lifestyle Characteristics

The prevalences of diagnosed type 2 diabetes, pre-diabetes, and undiagnosed (undetected) diabetes type 2 across different socio-demographic and lifestyle characteristics levels were calculated. To create the final dataset, data manipulation, cleaning, grouping and creating the variables of interest were done. The socio-economic factors including age, sex, income, education, physical activity, smoking, alcohol intake, and ethnicity were classified into their corresponding categories. For the age variable, the specific categories were developed including 20 to 39, 40 to 59 and 60 to 79 years. The household income variable in CHMS was used in this study. Also, the CHMS household questionnaire classification for education was used: less than secondary, secondary, other post-secondary and post-secondary graduate levels. In this survey, the Physical Activity Index with active, moderately active and inactive categories was used to evaluate the daily physical activity. The total DEE (kcal/day) was used to assign cut-offs for different categories of physical activity as follows: inactive ($0\leq$ DEE < 1.5), moderate activity ($1.5\leq$ DEE <3) and active (DEE ≥ 3) levels (Statistics Canada, 2011, 2014). Alcohol intake was categorized into two categories of "ever" drinker and "never" drinker; smoking was categorized as smoker and non-smoker, and ethnicity was categorized as White and non-White, as we have previously reported.

6.3.5. Data Analysis

Statistics Canada provided instructions on combining the first two cycles that were followed (Statistics Canada, 2014). Weighting and bootstrapping were applied to obtain generalizable results. The prevalence of diagnosed type 2 diabetes, pre-diabetes, and undiagnosed (undetected) type 2 diabetes variables were determined across demographic and socioeconomic factors as frequencies. Non-overlapping 95% CIs of the prevalence were used to estimate the significant difference of diabetes prevalence among different categories of socio-demographic variables. The dietary intake was determined as times per day, mean ± standard error; and the independent t-test was used to assess the significance between these means. According to Statistics Canada's recommendations, the degree of freedom of 24 was used for the combined data (11 degrees of freedom from CHMS Cycle 1 in addition to 13 degrees of freedom from CHMS Cycle 2) (Statistics Canada, 2014). Alpha is set at 0.05 to detect statistically significant differences. STATA/SE (v11, StataCorp LP., College Station, U.S.) and IBM SPSS Statistics for Windows (v20, IBM Corp., Armonk, U.S.) were used for data preparation and statistical analysis, respectively.

6.4. Results

The results of this study are representative of 23,022,889 Canadians aged 20-79 years. Among this population, 12.4% had pre-diabetes, and 7.5% had type 2 diabetes (diagnosed or undetected) (Figure 6.1). Among individuals with diabetes, 37.3% of them were not aware of their disease, which translates to 2.8% undiagnosed (undetected) diabetes cases among Canadians 20-79 years.

All three diabetes categories were more prevalent among older ages (60-79y) compared to younger ages (20-39y) ($p<0.001$) (Table 6.2). There were more cases of diagnosed diabetes ($p<0.001$) and pre-diabetes ($p=0.001$) among less educated individuals compared to the higher educated. Diagnosed diabetes was more prevalent among individuals with lower-middle income compared to the highest income ($p=0.002$). Diagnosed and undetected diabetes were both more prevalent among the physically inactive group compared to the active group ($p=0.026$ and 0.011 for diagnosed and undetected diabetes, respectively) and moderately active group ($p=0.054$ and 0.036 for diagnosed and undetected diabetes, respectively). No significant differences were observed across categories of sex, alcohol intake, smoking status, and ethnic groups (Table 6.2).

Among all the food categories that were evaluated, individuals with diagnosed diabetes consumed less fruit and vegetable juice ($p=0.002$) and ice-cream ($p=0.02$) and more potatoes ($p=0.005$) and diet soft drinks ($p<0.001$) compared to other foods (indicated in Table 6.3). No significant difference was observed in other food groups. In further analysis we conducted, after comparing the diet of those with diagnosed diabetes with those with prediabetes and undetected diabetes, we found that diagnosed diabetes individuals had lower intakes from ice-cream and higher intakes from diet drinks and fruit and vegetables juice compared to those with undetected diabetes/prediabetes.

Table 6. 2. Prevalence of diagnosed type 2 diabetes, pre-diabetes, and undiagnosed (undetected) type 2 diabetes by socio-demographic characteristics of Canadian adults, Canadian Health Measures Survey, Cycles 1 & 2, 2007-11 (n= 6,807).

	Diagnosed diabetes prevalence (%) [Standard Error] (95% Confidence interval)	**Pre-diabetes prevalence [Standard Error] (95% Confidence interval)**	**Undetected diabetes prevalence [Standard Error] (95% Confidence interval)**
Age			
20-39	F	5.1[1.32] (2.4-7.9)[a b E]	F
40-59	4.2 [0.69] (2.8-5.7)[a]	13.8[2.34] (8.9-18.6)[a c E]	4.1[1.0] (2.0-6.1)
60-79	13.1[0.84] (11.3-14.7)[a]	22.2[2.91] (16.2- 28.2)[b c]	4.6[1.02] (2.5-6.7)
Education			
Less than secondary	12.2 [1.58] (8.9-15.4) [a b]	17.4[3.07] (11.1-23.7)[a E]	3.9 [1.1] (1.4-6.3)[E]
Secondary	4.0[0.58] (2.8-5.2)[a]	15.9[2.46] (10.8-20.9)[b]	2.0 [0.5] (1.0-3.0)[E]
Other post-sec	F	5.6 [1.61] (2.3-9.0)[a b E]	3.0 [0.9] (1.1-4.9)[E]
Post-sec graduate	3.5[0.35] (2.8-4.2) [b]	11.2[1.88] (7.3-15.1)	2.8 [0.7] (1.4-4.2)[E]
Physical Activity			
Active	3.2[0.75] (1.6-4.7)[E]	9.3[2.43] (4.2-14.3)	1.8[0.46] (0.8-2.7)
Moderately active	3.6[0.44] (2.7-4.5)[a]	11.5 [2.1] (7.3-15.7)	1.8[0.58] (0.6-3.0)[E]
Inactive	5.8[0.63] (4.5-7.1)[a]	14.0 [2.] (9.9-18.1)	3.7[0.78] (2.0-5.3)[E]
Income			

Lowest income	5.7[1.49] (2.6-8.7)[E]	13.8 [3.5] (6.7-21.1)[E]	F
Middle-lower income	7.6[0.88] (5.8-9.5)[ad]	13.4[2.3] (8.7-18.2)[E]	2.9[0.8] (1.2-4.7)[E]
Middle-higher income	5.3[0.59] (4.1-6.5)	14.6[2.5] (9.5-19.7)[E]	3.3[0.9] (1.4-5.2)[E]
Highest income	3.3[0.57] (2.2-4.5)[a E]	10.5[1.6] (7.2-13.9)	2.5 [0.5] (1.4-3.6)[E]

[E] Coefficient of variation from 16.6% to 33.3%, recommended to be used with caution.

[F] Coefficient of variation >33.3%, unreliable for publishing based on Statistics Canada's recommendation.

Labeled prevalence in a row for each variable with a common superscript letter a, b, or c differ significantly with each other (p-value=0.05)

Table 6. 3. Dietary consumption among Canadians aged 20-79 years for diagnosed diabetes versus the rest of the population aged 20-79 (n=6,807) (Only foods with statistically significant intake difference between the two groups are presented).

Food/food group category*	**Diagnosed diabetes groups**	**The rest of the population**
	Serving /day † (95% confidence interval)	
Ice-cream	0.10 (0.09- 0.11)	0.12 (0.11-0.13)
Potato (including all types)	0.49 (0.43-0.56)	0.4 (0.37-0.43)
-Including baked, boiled, mashed or potato salad, excluding sweet potatoes and any type of fries.	0.36 (0.31-0.41)	0.27 (0.25-0.29)
Diet soft drinks	0.42 (0.29-0.56)	0.15 (0.13-0.17)
Fruit and vegetable juice	0.54 (0.46-0.61)	0.66 (0.62-0.7)

* There is a significant difference for all foods presented in this table between the two groups.
† The serving was reported for a year and for analysis, it has been divided by 365 days to obtain daily intake.

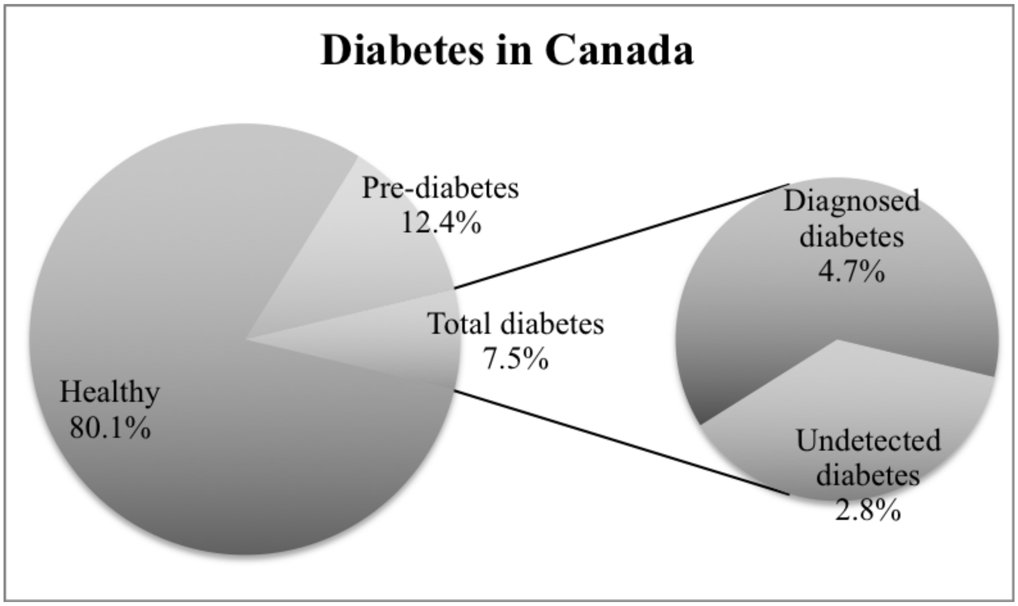

Figure 6.1. Prevalence (by weight to be nationally representative) of pre-diabetes, undetected diabetes and diagnosed diabetes among Canadians (20-79y), Canadian Health Measures Survey, Cycles 1 & 2, (2007-2011)

6.5. Discussion

This is the first study in Canada to investigate the prevalences of diagnosed type 2 diabetes, pre-diabetes, and undiagnosed type 2 (undetected) diabetes across different socio-demographic and lifestyle factors using a nationally representative sample with objective health measures (n=6,807). Also, this is the first study to compare the diet of groups with diagnosed diabetes with the rest of the population among Canadian adults. Based on this study, more than three out of ten Canadian adults with diabetes are unaware of their diabetes. Further, diabetes prevalence increased by age and people in the lower education and income categories were shown to have a higher prevalence of diabetes or pre-diabetes than in higher categories. Based on our results, individuals with diagnosed diabetes had partly different food intake from some foods compared to the rest of the population.

In 2009, in Canada, a report entitled *An Economic Tsunami* forecasted diabetes (including all types) to rise from 4% in 2002 to 7.3% in 2010 (Canadian Diabetes Association, 2010). This later value (7.3%) is close to our finding of 7.5% for type 2 diabetes alone. This forecast continued to suggest a prevalence of 10.8% for the year 2020, which could turn out to be an underestimation of the problem. Results of the present study showed that the prevalence of undiagnosed type 2 diabetes and pre-diabetes were 2.8% and 12.4%, respectively, which together show 15.2% with or at-risk for type 2 diabetes, as also reported by Rosella et al. (2015). The slight difference between their results and the results from our study could be due to the difference between the samples used in each study. The present study included almost double the sample previously used by Rosella et al. (2015) giving results with a higher statistical power (n=3,494 for Rosella et al., (Rosella et al., 2015) and n=6,807 for the present study). Our finding of more than three undiagnosed cases out of every ten diabetes cases in Canada is in agreement with what was reported for the U.S. adult population (Menke, Casagrande, Geiss, & Cowie, 2015).

The use of HbA1C values to diagnose type 2 diabetes is necessitated by its use in large survey data. The National Health and Nutrition Examination Survey, conducted in the United States measured OGTT, fasting plasma glucose and HbA1c of the respondents (Cowie et al., 2010), compared the sensitivity of these three methods: the OGTT had the highest detection rate, followed by the fasting plasma glucose and then the HbA1C method (Cowie et al., 2010). In contrast, a Canadian study using CHMS data has indicated a higher prevalence rate obtained by HbA1c method compared to a fasting plasma glucose method (Rosella et al., 2015). As the HbA1c levels indicate average blood glucose for the past two to three months, less day-to-day variability is observed in this blood glucose measurement test (World Health Organization, 2011). More importantly, fasting is not a requirement for the HbA1c test (World Health Organization, 2011). Fasting is not possible for large survey participants to attend the clinic in the afternoon. However, OGTT data is not available at the national level in Canada. Thus the results of our study may be underestimating the prevalence of diabetes in Canada.

In the present study, the prevalence of type 2 diagnosed diabetes was higher in the lower socioeconomic status, as indicated by lower levels of education and income. This result is in agreement with what was reported by other Canadian researchers using the National Population Health Survey (Ross, Gilmour, & Dasgupta, 2010). Based on this longitudinal study, researchers found higher chances of developing diabetes for people in lower income groups even after adjusting for other demographic and lifestyle factors. However, socio-demographic and lifestyle factors such as obesity and physical activity mediated the effect of education (Ross et al., 2010).

Similarly, in the present study, a higher prevalence of diagnosed diabetes was found among physically inactive individuals compared to active individuals. In a systematic review conducted on studies evaluating the association of diabetes risk and physical activity, researchers reported up to five to seven hours of leisure time physical activity per week reduces the risk of diabetes (Aune, Norat, Leitzmann, Tonstad, & Vatten, 2015). One reason for not observing a significant difference between the prevalence of diabetes across different levels of smoking status, alcohol intake and ethnicity is the small sample sizes for different levels of these variables.

Based on this study, the lower intake of ice-cream, juice and greater intake of diet soft drinks and potato may be indicative of adherence to the recommendation of eating more complex carbohydrates with lower glycemic indices rather than simple carbohydrates (Cheng, 2013). Further, these results may be questioned whether the difference is because of the "diagnosis" of diabetes or not. However, the further analysis showed the difference in the intake of those with diagnosed diabetes may be likely due to the diagnoses of the disease and therefore, dietary modification.

We previously showed in a study based on CHMS Cycle 1 data that individuals with MetS and diagnosed diabetes had significantly less fruit and vegetable juice intake compared to individuals that were not diagnosed with diabetes (Setayeshgar, Whiting, & Vatanparast, 2012). Therefore, screening and diagnosis of type 2 diabetes can lead to positive dietary modifications towards a healthier diet and ultimately better health/disease status. Moreover, from a research perspective, as individuals with type 2 diagnosed diabetes seem to alter their diet, in evaluating the association between dietary intake and risk of chronic diseases at the population level, individuals with diagnosed type 2 diabetes should be evaluated separately.

There were a few limitations including the use of cross-sectional data for the present study. Therefore, we should be cautious in interpreting the results of diabetes across different socio-demographic and lifestyle factors, as causality cannot be implied. Second, the HbA1c test may be affected by hemoglobin and red blood cell-related diseases such as anemia (World Health Organization, 2011); however, research has shown that the prevalence of these types of diseases is low among Canadians (Cooper, Greene-Finestone, Lowell, Levesque, & Robinson, 2012). Third, in Canada, only fasting plasma glucose and/or HbA1c have been included in national surveys. Fourth, the FFQ used in CHMS is a valuable tool to demonstrate differences across socio-demographic and lifestyle variables; however, a few food items in the group of grains and milk and alternatives were omitted.

6.6. Conclusion

In conclusion, a considerable proportion of the Canadian adults were unaware of their type 2 diabetes or pre-diabetic status. Therefore, they are at risk of not following the lifestyle modification recommendations as individuals with diagnosed diabetes do. Those who were aware had a lower intake of sugar-containing foods. Also, the higher prevalence of diabetes among populations in lower socioeconomic status levels should draw researchers' attention to conducting interventional studies among these populations with the aim of preventing and controlling diabetes among them. Our findings also suggest that in evaluating the association between dietary intake and risk of chronic diseases, cases with diagnosed diabetes should be excluded.

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CHAPTER 7: "Fast food" Dietary Pattern Increases the Risk of Metabolic Syndrome Among Canadian Older Adults Regardless of Body Mass Index, Canadian Health Measures Survey 2007-11

Based on the results from Chapter 6, we found that people with diabetes had a different intake from a few foods that may indicate their dietary modification. Thus, in this chapter and Chapter 8, we have evaluated the association of MetS and CVD risk and dietary patterns, and cases with diagnosed diabetes are excluded from the study population when evaluating these associations.

7.1. Abstract

Research has shown that diet is a key factor that impacts MetS. For metabolic disorders such as MetS, studies have indicated that dietary patterns as a holistic approach may be more useful than investigating individual dietary components**.** This study aimed to determine the association between dietary patterns and MetS among Canadians 12-79 years using nationally representative data. Using the cross-sectional CHMS combined Cycles 1 and 2 data from 2007-11, food group intakes of Canadians (ages 12-79 years) were obtained. The PCA method was used to determine the dietary patterns. Using logistic regression, the association between MetS and dietary patterns, controlling for potential covariates, was investigated for age groups of 12-19, 20-49 and 50-79 years. Survey data were weighted and bootstrapped to be representative at the national level. The MetS prevalence was 16.9% among Canadians 12-79 years (n=4,272, males=49.6%), representative of 26,038,108 Canadians aged 12 to 79 years. MetS was significantly different across different socio-demographic variables including age, income, education, smoking, having a family physician and physical activity. A "healthy/healthy-like" and "Western/fast food" dietary pattern emerged in all three age groups. In the older adult (50-79 years) group, the "fast food" dietary pattern with positive loadings of hotdogs, sausage/bacon, chips, fries, and diet soft drinks was associated with 27% (odds ratio=1.26; 95% CI: 1.04 to 1.54; p=0.0195) higher likelihood of having MetS. When adjusted for BMI in the model, the association remained significant (odds ratio=1.26; (95% CI: 1.016 to 1.55; p=0.035). No significant association was observed for younger age groups.

Our findings indicate that a “Fast food” dietary pattern is associated with an increased risk of MetS among Canadian adults. These results warrant further investigation using prospectively designed studies.

7.2. Introduction

CVD and diabetes are the leading causes of death worldwide and in Canada (WHO, 2018). To reduce the incidence of these diseases, we need to understand the underlying related risk factors. The MetS includes five components, which are risk factors related to CVD and diabetes (Esposito et al., 2004). Based on the joint statement by the IDF and the AHA/NHLBI having three or more of these CVD-related risk factors including abdominal obesity, hyperglycemia, hypertriglyceridemia, lowered high-density cholesterol and hypertension indicates the presence of MetS in an individual (Alberti et al., 2009b).

Research has shown that diet is a key factor that impacts MetS, and dietary patterns as a holistic approach may be more useful than investigating individual dietary components (Martínez-González & Martín-Calvo, 2013). In most population-based studies evaluating the association of MetS and dietary patterns, the “Western” dietary pattern has been shown to increase the risk of MetS (Heidemann, Scheidt-Nave, Richter, & Mensink, 2011; Panagiotakos et al., 2007). Moreover, Several studies had extracted a “Healthy” dietary pattern; however, the “Healthy” dietary pattern showed to have an association with MetS only in a few studies (Esmaillzadeh et al., 2007; Panagiotakos et al., 2007). Further, more heart-healthy specific diets such as the Mediterranean diet have been found to reduce the risk of MetS in most population-based studies (Kesse-Guyot et al., 2013; Rumawas et al., 2009).

A large national survey, CHMS, that includes objective health and nutrition data has been conducted in Canada, since 2007 (Statistics Canada, 2012b). The aim of this study is, for the first time, to evaluate the status of MetS by socio-demographic and lifestyle factors among Canadians and to determine the association between dietary patterns prevalent among Canadians (12-79 years) and MetS using CHMS nationally representative data. We hypothesized that the prevalence of MetS and its defining components are higher in Canadians with lower income and education level and Canadians who are inactive, frequent alcohol users, smokers. Individuals with MetS have less healthy dietary patterns and consume less vegetable and fruits and milk and alternatives than other Canadians.

7.3. Subject and Methods

7.3.1. Participants and Study Design

The CHMS is a cross-sectional nationally representative health survey that runs in bi-yearly cycles throughout Canada. This survey is conducted by Statistics Canada in collaboration with Health Canada and the Public Health Agency of Canada. The main aim of this survey is to fill the gaps in Canadian health information. Health Canada's Research Ethics Board has obtained ethics approval for this survey (Statistics Canada, 2011, 2012b, 2014).

Respondents gave written consent before their participation. Initially, an interview is held at the household using the “household questionnaire”. This interview collects socio-demographic, lifestyle and thorough self-reported health information. A few days after the household interview, the participant visits the MEC for another interview that is conducted using the CHMS “clinic questionnaire” and to give urine and blood samples (Statistics Canada, 2011, 2014). Cycle 1 of this survey was conducted starting from 2007 and ending in 2009, and included approximately 5,600 participants aged six to 79 years; Cycle 2 ran starting from 2009 and ended in 2011, and included approximately 6,400 participants with ages three to 79 years (Statistics Canada, 2011, 2014). This survey was designed to include up to 96% of the target population (6-79 years for Cycle 1 and Canadians 3-79 years for other cycles) (Statistics Canada, 2012b, p. 2). Canadians living on reserves/remote communities or in other Aboriginal settlements, institutionalized residents, and Canadian Forces full-time members were excluded from this survey (Statistics Canada, 2012a). The CHMS was conducted via a multistage sampling procedure, including the sampling of “collection sites” which were geographical units, “dwellings” and finally at the level of individuals residing in the dwellings (Statistics Canada, 2012b, 2012a). The combined Cycles 1 and 2 “full sample” data file (n=11,387, ages 6-79 years), combined “fasted subsample” data file (n=5,427 respondents, had fasted for a minimum of 10 hours) and the combined “weight files” (file that includes the weights of respondents of the combined CHMS Cycles 1 and 2) were used (Statistics Canada, 2014). The combined fasted subsample response rate was 46.3% (explanation for non-response is included in the CHMS Data User Guide (Statistics Canada, 2012a). For the present study, we used the combined Cycles 1 and 2 fasted subsample data for non-pregnant individuals with no diagnosed diabetes (due to their modified diet based on recommendations they receive from health professionals (Nöthlings et al., 2011)) that were 12 to 79 years old. The total number of respondents included in this study was 4,272, which were representative of 26,038,108 non-pregnant Canadians aged 12 to 79 years with no diagnosed diabetes.

7.3.2. Dietary Assessment

We used the usual dietary intake data collected using the FFQ through the CHMS household questionnaire. This FFQ was used to collect the usual dietary intake of foods per day. A total of 32 questions from seven food groups of CHMS were included in our analysis (Table 4.2). The six groups were as follows: meat; milk and dairy products; grains, fruits and vegetables; dietary fat; and, water and soft drink consumption (Statistics Canada, 2011) (additional details of the FFQ are described in Section 4.3.3 of this thesis). The 32 questions on the frequency of the intake from food items were used in the dietary pattern analysis of our study to compare individuals with MetS and individuals without MetS.

7.3.3. Metabolic Syndrome

This Study included ages 12-79 y. It is recommended to use the adult MetS criteria for ages 16 and above (Zimmet et al., 2007). For ages 12-15 years the 2007 IDF cut-off was used to determine MetS (Zimmet et al., 2007). The unified definition of MetS was used to assess MetS prevalence amongst 16-79 year olds (Alberti et al., 2009b). Thus, having at least three of the five components of MetS including elevated waist circumference; fasting plasma glucose; systolic or/and diastolic blood pressure; and triglycerides and reduced HDL-C would define the presence of MetS in a participant. Alberti et al. (Zimmet et al., 2007) recommended using ethnic or country-specific waist circumference cut-offs for the abdominal obesity component, which were used in this study.

Blood pressure reported was the average of five times measurements taken with one-minute intervals following a five-minute resting period. The blood pressure was taken using a validated electronic automated oscillometric device (BpTRU™ Medical Devices Ltd., Coquitlam, British Columbia) recommended by the Canadian Hypertension Education Program and Committee of Hypertension and Survey Experts (Bryan, Saint-Pierre Larose, Campbell, Clarke, & Tremblay, 2010). Waist circumference was measured using the WHO and the National Health Institute protocols (Statistics Canada, 2014). A phlebotomist drew blood from the median cubital or cephalic veins of the left arm preferably using a standardized venipuncture technique (fasting and non-fasting participants) (Bryan et al., 2010). The measurements we used for this study were fasted blood measurements of glucose (2 milliliters (mL) light grey VWR Cryogenic tubes), insulin and lipids (Bryan et al., 2010). For more detailed information, please refer to the CHMS user guides (Statistics Canada, 2011).

7.3.4. Socio-demographic and Lifestyle Characteristics

The socio-economic and lifestyle factors including age, sex, income, education, physical activity, smoking, alcohol intake, ethnicity, and having a family doctor were classified into their corresponding categories. For the age variable, specific categories were developed including 12 to 19, 20 to 49 and 50 to 79 years. The household income variable included four income levels including the lowest, lower middle, upper middle and highest income levels (Statistics Canada, 2011). Education was categorised as less than secondary, secondary, other post-secondary and post-secondary graduate levels (14). In this survey, the Physical Activity Index was used to determine the total DEE. Thus, physical activity was categorised based on the DEE (kcal/day) inactive ($0 \leq$ daily energy expenditure < 1.5), moderate activity ($1.5 \leq$ daily energy expenditure<3) and active (daily energy expenditure ≥ 3) levels (Statistics Canada, 2011). Alcohol intake had two categories of "ever" drinker and "never" drinker. Smoking was categorized to the current smoker, former smoker, and non-smoker categories, and self-reported ethnicity was categorized into one of the following : White; Aboriginal, Middle East, Mediterranean, Sub-Saharan African, and West Asian; Asian, South Asian and Latin American; and Chinese & Japanese (Statistics Canada, 2011). Having a family doctor was also included in the analysis as yes or no (14).

7.3.5. Data Analysis

Statistics Canada provided instructions for combining the first two cycles (Statistics Canada, 2014). To create the final dataset, data manipulation, cleaning, grouping and creating the variables of interest were done. The prevalence of MetS and its components were determined across socioeconomic and lifestyle factors as frequencies (% (standard error), two-sided 95% CI). Comparison of 95% CI and non-overlapping CI's were used to estimate the significant difference of MetS prevalence among different categories of the aforementioned variables and by adjusting for multiple comparisons. The dietary intake was determined as mean ± standard error and two-sided 95% CI, and the significance was determined by non-overlapping CI of the means between the MetS group and the group without MetS. According to Statistics Canada's recommendations, the degree of freedom of 24 was used for the combined data (11 degrees of freedom from Cycle 1 in addition to 13 degrees of freedom from Cycle 2) (Statistics Canada, 2014). Participants with missing data on some variables of interest were included in the analyses. Alpha was set at 0.05 to detect statistically significant differences. The SAS for Windows software (release 9.4, SAS Institute, Cary, North Carolina, U.S.) was used for statistical analysis.

The dietary pattern analysis was conducted for each age group of our sample including ages 12-19, 20-49 and 50-79 years (separating adolescents, younger adults, and older adults based on the difference in recommended dietary intake for different age groups). In order to extract the dietary patterns from 32 food groups, the PCA (PROC FACTOR) method was used. These factors explained about 52, 53 and 51% of the variation in the data for ages 12-19, 20-49 and 50-79 years. The varimax rotation method was used to obtain more interpretable results (Moeller et al., 2007). The varimax rotation produces uncorrelated factors that could be adjusted in the models. This is due to the fact that an individual has a score for all dietary patterns. In this method, components are obtained by grouping correlating food intake variables in order to derive uncorrelated variables (components). Four dietary patterns were retained for each age group based on the scree-plot method (additional analysis included in Appendix B) (Moeller et al., 2007). The names of the dietary patterns were chosen based on the content of the foods with a factor loading cut-of of ±0.25.

Logistic regression was used to assess the magnitude of the association between the four extracted dietary patterns from the CHMS dietary intake data and MetS. The multivariate-adjusted odds ratio and two-sided 95% CI were used to report the association between MetS and dietary patterns. Three models were used: model I adjusting for age and sex; and model II adjusting for age, sex, income, education, physical activity, alcohol intake, ethnicity, smoking, and other dietary patterns 1 to 4. In addition, in model III, we adjusted for all the covariates and BMI. Weighting and bootstrapping were done to be able to report nationally representative results.

7.4. Results

7.4.1. Metabolic Syndrome and Socio-demographic/Lifestyle Characteristics

The sample from CHMS combined Cycles 1 and 2 (n=4,272, males=49.6%) and was representative of 26,038,108 Canadians aged 12 to 79 years. Based on this study, MetS was prevalent among 16.9% of Canadians aged 12-79 years. The prevalence was 2.4% for 12-19 years, 11.5% for 20-49 years and 30% for 50-79 year olds. The most prevalent component of MetS among Canadians was abdominal obesity (32.5%) followed by reduced high-density cholesterol (27.7%) and elevated blood pressure, triglycerides and fasting plasma glucose (23.1, 22.6 and 13.7%, respectively). Further, 62.0% of the total population had at least one component of MetS present, and 34% had at least two components of MetS present. The prevalence of people with one, two and three components of MetS by age groups are presented in Figure 7.1, indicating a significant difference among age groups in all three categories ($p<0.005$). Individuals with MetS were older (39 versus 52 years, $p<0.001$) and had higher BMI (25.14 versus 32.31 kg/m^2 ($p<0.001$), waist-to-hip ratio (0.88 versus 0.98, $p=0.006$), weight (71.2 versus 93.06 kilograms, $p<0.001$), and Homeostatic Model Assessment of Insulin Resistance (1.78 versus 4.26, $p<0.001$) compared to people without MetS. The population with lower-middle income (25.8%) had higher MetS prevalence compared to upper-middle income level (14.1%, $p=0.031$) (indicated in Table 7.1). In addition, groups with some post-secondary (12.2%, $p=0.003$) and post-secondary graduation (14.2%, $p=0.001$) education levels had lower prevalence's of MetS compared to groups with less than secondary (36.2%) education.

Physically active groups had a lower prevalence of MetS (9.3%) compared to moderately active (18.7%, $p=0.002$) and inactive Canadians (19.8%, $p<0.001$). In addition, former smokers (24.0%) had higher MetS prevalence compared to non-smokers (13%, $p=0.002$). Canadians with MetS had less intakes from nuts, eggs, pasta, and sport drinks, and more intake from diet soft drinks, compared to the rest of the population (indicative by having no overlap of the two-sided 95% CI's of the means of these data). No other significant differences were observed in the intake from food groups between the MetS and non-MetS categories (Table 7.2).

7.4.2. Dietary Patterns

The four extracted dietary patterns and the corresponding factor loadings of food/food groups on the patterns by each age group (12-19, 20-49 and 50-79 years of age) of our sample are presented in Table 7.2.

For ages 12-19 years, the first dietary pattern was the "Western" dietary pattern with positive loadings of red meat, hotdogs, sausage/bacon, chips, fries, diet soft drinks, regular soft drinks, and sport drinks. The second dietary pattern was named the "Healthy-like" dietary pattern with positive loadings of fruits, tomato/tomato sauce, "other" vegetables (i.e. vegetables other than tomatoes, lettuce, green leafy salad, spinach/mustard greens /collards and potatoes), yoghurt, diet soft drinks and negative loadings of regular soft drinks and fruit juice. The third dietary pattern was the "Salad and condiments" dietary pattern with positive loadings of tomato/tomato sauce, lettuce/green vegetables, spinach/ mustard greens/collards, "other" vegetables (i.e. vegetables other than tomatoes, lettuce, green leafy salad, spinach/mustard greens /collards and potatoes), and salad dressing/mayonnaise and the last dietary pattern was the "Protein/rice" dietary pattern with positive loading of red meat, non-liver organ meat, beans, nuts, eggs, spinach/mustard greens/collards, and rice.

For ages 20-49 years, the first dietary pattern was the "Western" dietary pattern with positive loadings of red meat, hotdogs, sausage/bacon, eggs, baked/boiled/mashed potatoes, chips, fries, white bread, pasta, diet soft drinks. The second dietary pattern was the "Healthy-like" dietary pattern with positive loadings of nuts, fruits, tomato/tomato sauce, lettuce/green vegetables, spinach/mustard greens/collards, "other" vegetables (i.e. vegetables other than tomatoes, lettuce, green leafy salad, spinach/mustard greens /collards and potatoes), yoghurt and salad dressing/mayonnaise. The third dietary pattern was the "Nuts, fruits and vegetables, dairy and cereal" dietary pattern with positive loadings of nuts, fruits, other vegetables, milk, yogurt and cereal, and the last dietary pattern was the "Organ meats" dietary pattern with the positive loading of liver and other organ meats.

For ages 50-79 years, the first dietary pattern was the "Healthy-like" dietary pattern with positive loadings of nuts, fruits, lettuce/green vegetables, spinach/mustard greens/collards, "other" vegetables (i.e. vegetables other than tomatoes, lettuce, green leafy salad, spinach/mustard greens /collards and potatoes), cheese, yoghurt, diet soft drinks, and vegetable juice and negative loadings of regular soft drinks. The second dietary pattern was the "Salad and condiments" dietary pattern with positive loadings of tomato/tomato sauce, lettuce/green vegetables, and salad dressing/mayonnaise. The third dietary pattern was the "Fast food" dietary pattern with positive loadings of hotdogs, sausage/bacon, chips, fries, and diet soft drinks and the last dietary pattern was the "Meat and potato" dietary pattern with positive loading of red meat, sausage/bacon, eggs, baked/boiled/mashed potatoes and ice-cream/frozen yogurt.

7.4.3. Association Between Metabolic Syndrome and Dietary Patterns

Our results showed that after adjusting for all socio-demographic and lifestyle factors among ages 50-79 years the "Fast food" dietary pattern was associated with 27% (odds ratio=1.27;

95% CI: 1.04 to 1.54; p=0.0195) higher odds of having MetS (Table 7.3). When we adjusted for BMI in model III in addition to all other previously added variables from model II, the association remained significant (odds ratio=1.26; 95% CI: 1.016 to 1.55; p= 0.035). No significant association was observed between MetS and other dietary patterns for younger age groups.

Table 7. 1. Prevalence (weighted estimate) of metabolic syndrome across socio-demographic and lifestyle factors of Canadians aged 12 to 79, Canadian Health Measures Survey, combined Cycle 1 and 2, 2007–2011 (n=4,272, males=49.6%, was representative of 26,038,108 Canadians aged 12 to 79 years).

	Metabolic Syndrome, estimated prevalence % (SE)	**95% CI**
	Age (years)*	
12-19	2.4 (0.8)[E]	0.7-4.1
20-49	11.5 (1.3)	8.8-14.1
50-79	30.1 (2.2)	25.7-34.6
	Sex	
Males	18.1 (1.4)	15.2-21
Females	15.8 (1.7)	12.3-19.3
	Income	
Lowest	14.5 (3.4)[E]	7.5-21.6
Lower middle	25.8 (3.3)[a]	19.1-32.6
Upper middle	17.3 (1.7)	13.9-20.8
Highest	14.1(1.6)[a]	10.7-17.5
	Education	
<Secondary	36.2 (7.1)[a b E]	21.5-51
Secondary grad	22.7 (3.4)	15.6-30
Some Post secondary	12.2 (2.9) [a E]	6.3-18.1
Post secondary grad	14.2 (1.1) [b]	12.0-16.4
	Alcohol intake	
Ever	[F]	12.5-25
Never	16.5 (1.2)	14.0-19
	Ethnicity	
Caucasian	16.6 (1.2)	14.0-19.1
Aboriginal	[F]	7.7-53.7
Middle East, Mediterranean, Sub-Saharan African, and West Asian	17.8 (4.0)[E]	9.5-26
Asian, South Asian and Latin American	19.6 (4.1)[E]	11.1-28.1
Chinese & Japanese	[F]	0.8-25

	Physical activity	
Active	9.3 (1.1) [a b]	7.0-11.5
Moderately active	18.7 (2.2) [a]	14.2-23.3
Inactive	19.8 (1.8) [b]	16.2-23.5
	Smoking	
Current	18.6 (2.6)	13.2-24
Former	24.0 (2.2)[a]	19.5-28.6
Never	13.1 (1.4)[a]	10.2-15.9
	Family doctor	
Yes	18.2 (1.3)	15.56-20.87
No	10.95 (2.1)[E a]	6.54-15.37

CI, confidence intervals, SE, standard errors
[E] Coefficient of variation 16.6% to 33.3% recommended to be used with caution.
[F] Coefficient of variation from >33.3%, unreliable for publishing based on Statistics Canada's recommendation.
[*] Significantly different estimates between all groups based on 95% CI. Labeled proportions in a column for each variable with a common superscript letter significantly differ (p<0.05).

Table 7. 2. Food intake of Canadians aged 12 to 79 years with and without metabolic syndrome, Canadian Health Measures Survey, combined Cycles 1 and 2, 2007–2011 (n=4,272, males=49.6%, was representative of 26,038,108 Canadians aged 12 to 79 years).

Food/food groups*	**Without Metabolic Syndrome Mean (SE) (95% two-sided confidence interval)**	**With Metabolic Syndrome Mean (SE) (95% two-sided confidence interval)**
Meat and alternatives		
Red meat	161.68 (2.93) (155.62-167.74)	158.28 (7.06) (143.70-172.86)
Liver	3.50 (0.45) (2.56-4.44)	5.03 (0.62) (3.75-6.31)
Other organ meat such as kidneys, heart or giblets	1.78 (0.37) (1.02-2.54)	1.25 (0.30) (0.64-1.87)
Hotdogs	18.39 (1.50) (15.30-21.47)	16.34 (1.96) (12.30-20.39)
Sausage	40.00 (1.91) (37.05 -44.94)	39.02 (4.16) (30.42-47.61)
Eggs/egg dishes	**104.94 (2.69) (99.39-110.49)**	**93.01 (3.27) (86.26-99.76)**
Beans	52.76 (3.79) (44.93-60.59)	40.44 (3.51) (33.19-47.70)
Nuts (excluding nut butters)	**102.78 (4.22) (94.07-111.49)**	**79.70 (4.60) (70.20-89.21)**
Dairy		
Milk	353.68 (11.92) (329.08-378.27)	295.85 (20.62) (253.31-338.40)
Cheese	13.98 (1.13) (11.65-16.30)	16.79 (2.30) (12.05-21.53)
Yogurt	137.07 (5.05) (126.66-147.48)	131.10 (9.21) (112.09-150.11)
Grains		
Cereal (hot or cold)	153.50 (3.94) (145.35-161.64)	152.35 (16.43) (118.43-186.26)
Brown bread	244.63 (5.970) (232.31-256.95)	227.13 (13.25) (199.78-254.48)
White bread	136.33 (5.87) (124.22-148.45)	155.29 (26.07) (101.48-209.11)
Pasta	**97.40 (1.586) (94.13-100.67)**	**72.94 (4.25) (64.18-81.71)**
Rice	115.97 (8.05) (99.36-132.58)	97.04 (9.36) (77.72-116.37)
Fruits and vegetables		

Fruits	460.62 (12.24) (435.37-485.88)	430.81(22.59) (384.18-477.45)
Tomato/tomato sauce	145.00 (3.98) (136.78-153.21)	149.37 (8.75) (131.31-167.44)
Lettuce/green leafy salads	160.20 (4.14) (151.65-168.74)	146.72 (8.23) (129.74-163.70)
Spinach/mustard greens/collards	46.35 (4.31) (37.45-55.25)	33.32 (3.36) (26.38-40.25)
Fries (any type including hash brown)	54.46 (2.60)(49.09-59.84)	47.10 (3.93) (38.99-55.20)
Baked/boiled/mashed potatoes	94.95 (3.97) (86.76 -103.16)	114.08 (8.65) (96.23-131.94)
Other [than mentioned] vegetables	350.20 (6.78) (336.21-364.20)	314.39 (24.36) (264.12-364.67)
Dietary fat		
Dressing/mayonnaise	121.027 (4.07) (112.63-129.42)	106.61 (6.94) (92.29-120.92)
Chips (any type excluding low-fat and pretzels)	59.28 (2.61) (53.89-64.68)	46.58 (4.32) (37.66-55.49)
Beverages		
Diet soft drinks	**44.35 (4.68) (34.70-54.00)**	**81.10 (12.63) (55.02-107.17)**
Regular soft drinks	93.92 (7.33) (78.79-109.05)	98.58 (13.60) (70.51-126.65)
Sport drinks	**21.53 (1.27) (18.92 -24.15)**	**8.92 (2.08) (4.63-13.21)**
Flavoured drink	50.87 (3.10) (44.46 -57.28)	39.65 (7.23) (24.73-54.57)
Fruit juice	209.04 (7.03) (194.53-223.56)	201.98 (16.51) (167.91-236.05)
Vegetable juice	32.06 (2.50) (26.90-37.21)	41.95 (6.72) (28.08 55.82)

Detailed descriptions of food groups/food are available in Table 4.2.
Bold values indicate a significant difference in the row based on 95% confidence interval non-overlap.

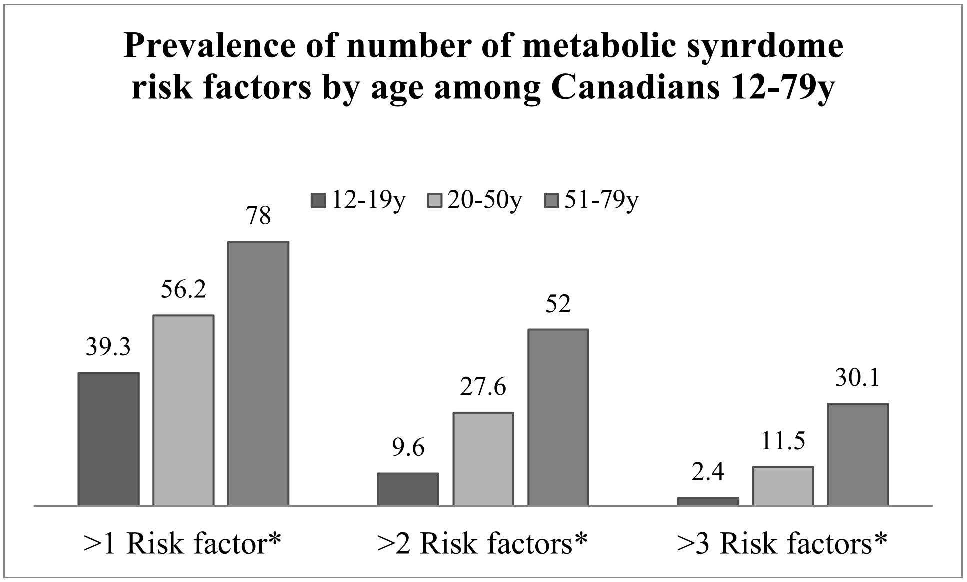

Figure 7. 1. This figure indicates the prevalence of groups with at least one, two and three components of metabolic syndrome across three age groups of 12-19, 20-50 and 51-79 years. Canadian Health Measures Survey combined Cycles 1 and 2, 2007–2011 (n=4,272, males=49.6%, was representative of 26,038,108 Canadians aged 12 to 79 years).

*. Indicates significance differences among prevalence of the three age groups.

Table 7. 3. Factor loadings from principal components analysis of dietary intake of Canadians 12-79 years, Canadians Health Measures Survey combined Cycles 1 and 2, 2007-11 (n=4,272).

Food/Food groups*	**Dietary patterns for 12-19 y**				**Dietary patterns for 20-49 y**				**Dietary patterns for 50-79 y**			
	F1†	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
Red meat	0.39‡	-	-	0.40	0.59	-	-	-	-	-	-	0.72
Liver meat	-	-	-	-	-	-	-	0.83	-	-	-	-
Other than liver organ meat	-	-	-	0.42	-	-	-	0.84	-	-	-	-
Hot Dogs	0.57	-	-	-	0.46	-	-	-	-	-	0.55	.
Sausage/bacon	0.59	-	-	-	0.59	-	-	-	-	-	0.29	0.55
Beans	-	-	-	0.25	-	0.24		-	-	-	-	-
Nuts	-	-	-	0.44	-	0.36	0.26	-	0.38	-	-	-
Eggs	-	-	-	0.59	0.35			-	-	-	-	0.38
Fruit	-	0.68	-	-	-	0.45	0.40	-	0.36	-	-	-
Tomato and tomato Sauce	-	0.25	0.27	-	-	0.50	-	-	-	0.58	-	-
Lettuce/Green vegetables	-	0.22	0.74	-	-	0.75	-	-	0.28	0.73	-	-
Spinach/mustard greens/collards	-	-	0.44	0.29	-	0.50	-	-	0.41	0.22	-	-
Baked/boiled/mashed potatoes	0.24	-	-	-	0.47	-	-	-	-	-	-	0.63
Other vegetables	-0.22	0.60	0.25	-	-	0.45	0.24	-	0.50	-	-	-
Milk	-	-	-	-	-	-	0.73	-		-	-	-
Cheese	-	-	-	-	-	0.21		-	0.33	-	-	-
Yogurt	-	0.56	-	-	-	0.28	0.47	-	0.48	-	-	-
Ice-cream/Frozen Yogurt	-	-	-	-	-	-	-	-	-	-	-	0.30
Salad Dressing/Mayonnaise	-	-	0.72	-	0.22	0.58	-	-	-	0.72	-	-
Chips	0.29	-	-	-	0.46	-	-	-	-	-	0.62	-
Fries	0.57	-	-	-	0.57	-	-	-	-	-	0.61	0.20
Brown Bread	-	-	-	-		-	-	-	-	-	-	-
White Bread	-	-	-	-	0.25	-	-	-	-	-	-	0.23
Rice	-	-	-	0.64		-	-	-	-	-	-	-
Pasta	0.21	-	-	-	0.36	-	-	-	-	-	0.21	-
Cereal	-	-	-	-		-	0.73	-	-	-	-	-
Diet soft drinks	0.46	0.33	-	-0.20	0.32	-	-	-	0.28	-	0.57	-
Regular soft Drinks	0.32	-0.30	-	-	-	-	-	-	-0.58	-	-	-
Sport Drinks	0.37	-	-	-	-	-	-	-	-	-	-	-
Flavoured Drinks	-	-	-	-	-	-	-	-	-	-	-	-
Fruit Juice	-	0.39	-	-	-	-	-	-	-	-	-	-
Vegetables juice	-	-	-	-	-	-	-	-	0.31	-	-	-

* Detailed description of the food/food groups are indicated in Table 4.2.

† F1-4: Dietary patterns 1-4

‡ Only factor loading scores below -0.2 and above 0.2 are shown in this table.

Table 7. 4. Multivariate-adjusted odds ratios for the association between metabolic syndrome and dietary patterns by age group, Canadians Health Measures Survey combined Cycles 1 and 2, 2007-11 (n=4,272, males=49.6%, was representative of 26,038,108 Canadians aged 12 to 79 years).

Age group	Factors	Model*	Odds Ratio	LCI†	UCI‡	P-value
12-19 years	F1	Model 1	2.29	0.58	9.04	0.236
		Model 2	2.36	0.09	60.83	0.604
	F2	Model 1	0.50	0.12	2.03	0.331
		Model 2	0.28	0.00	50.07	0.634
	F3	Model 1	0.82	0.37	1.82	0.621
		Model 2	0.78	0.09	6.91	0.830
	F4	Model 1	1.18	0.39	3.61	0.772
		Model 2	0.60	0.01	38	0.813
20-49 years	F1	Model 1	1.02	0.73	1.44	0.900
		Model 2	1.09	0.75	1.58	0.656
	F2	Model 1	0.79	0.59	1.06	0.110
		Model 2	0.83	0.61	1.14	0.255
	F3	Model 1	0.77	0.59	1.01	0.063
		Model 2	0.83	0.60	1.15	0.259
	F4	Model 1	1.21	0.88	1.65	0.244
		Model 2	1.14	0.74	1.75	0.552
50-79 years	F1	Model 1	0.86	0.66	1.11	0.233
		Model 2	0.90	0.69	1.17	0.438
	F2	Model 1	0.89	0.72	1.10	0.275
		Model 2	0.91	0.74	1.13	0.403
	F3	Model 1	1.25	1.03	1.51	0.021
		Model 2	1.27	1.04	1.54	0.020
		Model 3	1.26	1.02	1.55	0.035
	F4	Model 1	1.03	0.87	1.22	0.723
		Model 2	1.05	0.88	1.25	0.578

* Model 1 adjusted for age and sex; model 2 adjusted for age, sex, income, education, physical activity, alcohol intake, and other dietary patterns between 1-4; model 3 adjusted for all covariates in model 2 and body mass index.

† Lower 95% confidence interval

‡ Upper 95% confidence interval

7.5. Discussion

This is the first study evaluating the association between MetS and dietary patterns among Canadians 12-79y. The MetS prevalence was 16.9% among Canadians 12-79y with abdominal obesity being the most prevalent component of MetS. MetS was significantly different across levels of age groups, income, education, smoking, physical activity and having a family physician. One of the dietary patterns extracted from the older adult Canadian population called the “Fast food” dietary pattern increased the risk of MetS, regardless of their BMI.

7.5.1. Metabolic Syndrome and its Components Among Canadians

The MetS prevalence we obtained in our study was lower (16.9 versus 18%) than a study that had used only CHMS Cycle 1 data (Setayeshgar et al., 2012). The reasons for a lower rate in our study are that we excluded people with diagnosed diabetes and we used the IDF criteria to define MetS for adolescents. We made this decision due to the fact that individuals with diagnosed diabetes tend to modify their diet based on recommendations they receive from the healthcare provider (Nöthlings et al., 2011). In Canada from 1986-1992, the prevalence of MetS was reported to be 14.4% for ages 18-64y, thus comparing to our results, it indicates an increase among the adult population. Based on our results, the prevalence of MetS among the adolescent population was 2.4% similar to the results obtained by a Canadian study (10-18y) using similar criteria for adolescents (2.1%) (MacPherson, de Groh, Loukine, Prud’homme, & Dubois, 2016). Other studies have similarly reported a greater prevalence of MetS among older ages compared to younger (Guarner, Veronica, & Maria Esther, 2012; Setayeshgar et al., 2012). There are many phenomena that contribute to the association of aging and MetS such as increased oxidative stress and generation of free radicals (Guarner et al., 2012).

Regarding income levels, we found that MetS is most prevalent in individuals with lower middle income compared to the higher income category. This result was also observed in other studies for both sexes (Setayeshgar et al., 2012) and in a study on women (Dallongeville et al., 2005). A lower income status contributes to lower food security status, accessibility to the facility and/or time to have physical activity contributing to a higher risk for metabolic disorders(Brien & Katzmarzyk, 2006). Our results indicated that there is less risk of MetS among individuals who have a higher level of household education compared to lower ones, in agreement with other studies (Dallongeville et al., 2005; Guarner et al., 2012) . Higher education level provides knowledge in making healthier choices in food intake that can affect the status of MetS (Dallongeville et al., 2005).

Our results of observing less prevalence of MetS among the physically active group compared to the moderately active and the inactive groups were similarly observed in a study using a different Canadian cohort to assess the moderate-to-vigorous physical activity measured by 7-days Actical accelerometers (Brien & Katzmarzyk, 2006). These researchers found that physical activity has a strong association with the risk of MetS among Canadians 18-64 years. Physical activity not only affects the amount of body fat mass but more importantly the type of fat accumulation and reduces visceral fat tissue, which is an important factor in the development of MetS (Clarke & Janssen, 2013). Studies have indicated the preventive effect of exercise on insulin sensitivity, dyslipidemia, inflammation and blood pressure (Henriksen, 2002; Lakka & Laaksonen, 2007; Lee, 2005).

MetS prevalence was not significantly different between populations with different ethnic backgrounds in Canada, most likely due to small sample sizes and high variation in the sample of CHMS. Canada is a multiethnic country; hence, an ethno-specific approach was considered in studying MetS, i.e., using ethno-specific waist circumference cut-offs (Alberti et al., 2009b). Different ethnic groups with the same measures of central obesity are shown to have a different risk of CVD and diabetes (Abate & Chandalia, 2011). However, other ethno-specific cut-offs are needed in calculating MetS.

7.5.2. Association Between Metabolic Syndrome and Dietary Patterns

The “Fast food” dietary pattern observed among 50-79 year olds was associated with MetS in our study, which is in agreement with population-based studies results (Heidemann et al., 2011; Lutsey et al., 2008; Movassagh & Vatanparast, 2017). The reason for not observing this significant association among younger Canadians may be related to a lower prevalence of MetS in these age groups. Foods that had a positive loading on the “Fast food” pattern in our study have shown to increase the risk of MetS components and/or MetS in other studies. This dietary pattern included processed meats, which similarly were found to increase the risk of MetS in two studies conducted in Iran (Azadbakht & Esmaillzadeh, 2008) and the U.S. (Lutsey et al., 2008). Researchers indicate that saturated/trans fatty acids, nitrites, and advanced glycation end products are contributors to the increased risk of MetS and its components (Lutsey et al., 2008; Movassagh & Vatanparast, 2017).

Similar to studies conducted in the United States, chips, and fries as two high-fat content and processed foods were observed to have high loadings on the “Fast food” dietary pattern of the older adult population of our study (Deshmukh-Taskar et al., 2009; Statistics Canada, 2012b). More importantly, the partially hydrogenated vegetable oils content of these foods contribute to an increased trans fatty acid content of the diet which in return increases systemic inflammation, endothelial dysfunction, and insulin resistance (Study, 2015). Diet soda as a component of this dietary pattern has been found to be consumed more among people with MetS compared to ones without MetS in our study (ages 12-79 years). Similarly, other studies have found diet sodas to be associated with the risk of MetS, among European and American populations (Crichton, Alkerwi, & Elias, 2015; Langsetmo et al., 2010; Nettleton, Polak, Tracy, Burke, & Jacobs, 2009). Reverse causality, confounding the effect of other factors, and presence of an underlying pathophysiological effect of an ingredient of the diet drinks are mostly discussed (Crichton et al., 2015; Nettleton et al., 2009).

The "Healthy" dietary patterns emerged in our study in different age groups were characterized by high nutrient-dense foods. In agreement with our results, many other studies had not observed an association between this dietary pattern and MetS (Movassagh & Vatanparast, 2017). MetS has different components and features. Thus, it requires a dietary pattern that could affect all features of MetS at the same time such as the Mediterranean diet (Kesse-Guyot et al., 2013; Rumawas et al., 2009).

Our study is the first to investigate the association between MetS and dietary patterns among Canadians 12-79y using nationally representative data. We used objective health measures data from CHMS, which were collected from Canadians for the first time. Another strength is the dietary pattern approach, which illustrated a holistic picture of the dietary status and the fact that our outcome is a multi-featured syndrome. A limitation of our study was the FFQ used, which has omitted a few foods from the grains and the meat and alternatives groups. Our study is cross-sectional; thus causality cannot be concluded. In addition, the alpha posteriori method has a few researcher-oriented steps that reduce the reproducibility of the analysis.

7.6. Conclusion

The growing prevalence of obesity, metabolic abnormalities and MetS is associated with having a "Fast food" dietary pattern (i.e. 27% increased the risk of MetS among Canadians). This is important in terms of policy implications in the area of Nutrition and Health. The association between MetS and the "Fast food" dietary pattern remained significant after adjustment for all covariates suggesting the importance of diet quality/composition. Further investigation using prospectively designed studies is needed.

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CHAPTER 8: Risk of Atherosclerotic Cardiovascular Disease and Cardiovascular Age Gap and their association with Diet Among Canadian Adults 40-79 Years Using Cross-sectional Canadian Health Measures Survey data 2007-11

After investigating MetS and its association with dietary patterns among Canadians, in this chapter, we evaluated the absolute risk of CVD. Thus, we determined the 10-year risk of ASCVD and CAG for this purpose and their association with dietary patterns.

8.1. Abstract

Identifying groups at risk for CVD and improving prevention strategies are important due to the high rates of these diseases in Canada. We aimed to determine the 10-year ASCVD risk and CAG of Canadians 40-79 years and the association between prevalent dietary patterns and ASCVD risk, and CAG, using nationally representative data from CHMS. Health measures and dietary intake information were obtained from CHMS 2007-11. The estimated 10-year ASCVD risk and CAG were determined for ages 40 to 79 years across different factors. Dietary patterns emerged using the PCA method from 32 food groups. The association between 10-y ASCVD risk, and CAG, with dietary patterns, was investigated. Survey data were weighted and bootstrapped to be nationally representative. The mean 10-year ASCVD risk of 40-79y was 6.9% (representative of 13,655,671 Canadians aged 40-79 years). Our results showed that the mean CAG for men was -4.1 years (older) and for females was +0.4 years (younger). Four dietary patterns emerged. Of note, the “High carbohydrate and protein” dietary pattern, which included non-fried potatoes, red meat, sausage, egg and ice-cream/frozen yoghurt was adversely associated with 10-year ASCVD (P_{trend}= 0.0128). The “Healthy” and “Fast food” dietary patterns had an inverse ($p<0.0001$) and direct ($p=0.005$) association, respectively, with CAG adjusted for potential covariates. Dietary patterns prevalent among this population were associated with CAG and ASCVD risk. Interventions for promoting healthy dietary patterns may be beneficial to reduce ASCVD in Canada.

8.2. Introduction

The ASCVD are one of the top causes of mortality in Canada (Statistics Canada, 2018). This makes effective preventive strategies a priority in order to reduce the burden on the health sector. One approach is to identify people with a high risk of developing ASCVD using cardiovascular health assessment tools such as the ASCVD risk equations or the CAG tool (Reiner et al., 2011). The ACC/AHA in 2013, recommended assessing the 10-year risk of ASCVD for ages 40-79 years using pooled cohort based risk assessment equations (Goff et al., 2014). In addition, CAG, which is the difference between the vascular age and chronological age, has been of interest to researchers in the field of ASCVD prevention (D'Agostino et al., 2008). An individual's vascular age would be the age of a person if all risk factors were within an optimum range (Cuende, 2016). This tool is a beneficial approach to conveying cardiovascular risk messages to the general population (Cuende, 2016).

Diet is an important factor in developing and preventing ASCVD. Accordingly its association with ASCVD is of interest to researchers. Dietary patterns present a holistic picture of the real-life usual diet rather than the conventional approach of looking into one nutrient at a time (Hu, 2002). This approach allows researchers to understand how foods that provide combinations of related nutrients and have synergistic effects on one another (Hu, 2002) might influence ASCVD (Sonnenberg et al., 2005). Previously, researchers have found in cohort studies that in order to reduce the risk of developing ASCVD, a diet rich in whole grains, vegetables, and fruits, low in cholesterol and saturated fats, and limited in alcohol is recommended (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001; Freeland-Graves & Nitzke, 2002; Sonnenberg et al., 2005).

The CHMS, conducted since 2007, is the only national survey, which includes both objective health measures and dietary intake data (Statistics Canada, 2011). It permits calculation of 10-year ASCVD risk and laboratory-based CAG. Our two objectives are: to determine 10-year ASCVD risk and CAG of Canadian adults ages 40-79 years and across socio-demographic, lifestyle, metabolic and medication using factors; and to evaluate the associations of ASCVD risk and CAG and dietary pattern among this population. We hypothesized that the mean risk of ASCVD and mean CAG are higher for groups in the lower SES and lifestyle levels. The group with high ASCVD risk has less healthy dietary pattern compared to those with low risk.

8.3. Subjects and Methods

8.3.1. Participants and Study Design

The cross-sectional nationally representative health survey, CHMS, has been running in

Canada continuously since 2007 with biyearly cycles. It is conducted by Statistics Canada in collaboration with Health Canada and the Public Health Agency of Canada. Health Canada's Research Ethics Board obtained ethics approval for this survey. Respondents' consents are obtained before their participation (Statistics Canada, 2011, 2012). Cycles 1 and 2 were conducted from 2007 to 2011 and consisted of 5,600 (age 6 to 79 y) and 6,400 (age 3 to 79 y) respondents, respectively (Statistics Canada, 2011, 2012). This survey covers ~ 96% of the target population (Statistics Canada, 2011). Those excluded include institutionalized residents, Canadians living on reserves, in remote regions, and the Canadian Forces full-time members (Statistics Canada, 2012).

We used the data from Cycles 1 and 2 but only for those participants aged 40-79 years who had a fasted blood sample (Statistics Canada, 2011, 2012). The combined fasted sub-sample response rate was 47.2% compared to the full sample response rate of 53.5%(Statistics Canada, 2014). Then we further omitted pregnant individuals and those having CVD for descriptive analysis. For the analysis of the association of diet and ASCVD risk and CAG, we additionally excluded people with hypertension and diagnosed diabetes type 2 due to the likelihood of having a modified diet based on recommendations they received from health professionals (Nöthlings et al., 2011). The total number of respondents included in this study was representative of 13,655,671 Canadians aged 40 to 79 years.

8.3.2. Estimated 10-year Atherosclerotic Cardiovascular Disease risk for Ages 40-79y

The estimated 10-year ASCVD risk of ages 40-79 years was determined using the pooled cohort equations presented by the 2013 ACC/AHA Guidelines (Goff et al., 2014). The outcome for this method is the first ASCVD that includes non-fatal myocardial infarction, CHD death, and stroke (fatal or non-fatal). The risk factors included in these equations were age, total cholesterol level, HDL-C level, systolic blood pressure, blood pressure medication usage, diabetes, and smoking status. The risk was determined as 1 minus the baseline survival rate raised to the power of the exponential of the sum of "coefficient x individual (person) values" minus the sum of the age and ethnic-specific value as indicated in Equation 8.1 (Goff et al., 2014).

Equation 8.1. The equation for calculating individuals 10-year risk for a major atherosclerotic cardiovascular event within the next 10 years (Goff et al., 2014).

$$1 - S_{10}^{e\left(\sum(coefficeint_{in} \times Value_{in})\right) - Coefficinet_m \times Value_m)}$$ ……………………………..(8.1)

Where, “S” is survival rate at 10 years, “e” is natural exponential base, “in” is the individual’s value (summation of all his/her values x corresponding coefficients) and “m” is the race and sex-specific overall mean. The risk was used as continuous for descriptive analysis, and it was dichotomised into low and high categories with the cut-off of 7.5% (Goff et al., 2014) (high vs. low 10-year ASCVD risk) for regression analysis.

8.3.3. Risk Factors

We defined smoking as smoker and non-smoker. We determined diabetes based on the fasting plasma glucose level of ≥ 7 mmol/L or self-reported diagnoses of diabetes by a health professional. For more information regarding the procedure of taking the objective measurement, refer to CHMS user guide (Statistics Canada, 2011, 2012). We used the unified criteria of MetS and the ethnic/country specific cut-offs for waist circumference (Alberti et al., 2009).

8.3.4. Medication Users

Respondents that had reported using medications with Anatomical Therapeutic Chemical codes of C10A and C10B were categorized as blood lipid-lowering medication users (Hennessy, Bushnik, Manuel, & Anderson, 2015). Respondents that reported using ATC codes including C02, C03, C07, C08 and C09 (excluding C02KX01, C03BA08, C03CA01, C07AA07, C07AA12, C07AG02) (Hennessy et al., 2015) or self-reported using blood-pressure-lowering medication in the past month were categorized as antihypertensive medication users.

8.3.5. Dietary Assessment and Dietary Pattern Analysis

The usual dietary intake data was collected using a FFQ included in the CHMS household questionnaire. We used 32 items from the FFQ that are indicated in Table 4.2. The 32 food groups were the input variables for the PCA (PCA, PROC FACTOR). Using PCA, uncorrelated components were obtained from the 32 correlating food intakes input variables. Eleven dietary patterns had eigenvalue of above 1 based on Kaiser’s criterion, which explained about 52% of the variation in the data. For better interpretation we retained four dietary patterns to assess their association with ASCVD risks (details indicated in Appendix C) (Tucker, 2010). The Varimax rotation was used to obtain more interpretable results from uncorrelated factors (Tucker, 2010).

The names of the dietary patterns reflect the content of those foods with a factor loading cut-off of +/- 0.3.

8.3.6. Socio-demographic and Lifestyle Characteristics

We included the factors as follows age, sex, income, education, physical activity, smoking, alcohol intake, ethnicity, having an immediate family ember with premature CVD and having a family physician from what was observed in the literature and to address our fifth objective. For the age variable, age at the clinic was categorized by ten year intervals. The household income variable included four income levels: the lowest, lower-middle, upper-middle and highest income level. The education variable had four levels: less than secondary, secondary, other post-secondary and post-secondary graduate levels. The Physical Activity Index was a proxy for total DEE. Physical activity was categorised base on DEE (kcal/day) as inactive, moderately activate and active levels based on the DEE with cut-offs of 0, 1.5 and 3 DEE. Alcohol intake had two categories: “ever” drinker and “never” drinker. Self-reported ethnicity was categorized into two categories of white and non-white. Having a family physician was considered in the analysis as yes or no.

8.3.7. Data Analysis

The instructions from Statistics Canada on combining CHMS Cycles 1 and 2 (Statistics Canada, 2014), and followed cleaning, grouping and creating the variables of interest were used to obtain the combined file including the master files, the fasted-subsamples and the medication files. The prevalence of ASCVD risk and age-gap were determined across different factors as the mean of percent risk (±standard error, SE). Independent t-test and ANOVA was applied to estimate the significant difference of ASCVD risk prevalence among different categories of the aforementioned variables. According to Statistics Canada’s recommendations, the degree of freedom of 24 was applied for the combined data. The alpha was set at 0.05 to detect statistically significant differences. SAS for Windows software (release 9.4, SAS Institute, Cary, North Carolina, U.S) was used for analysis.

For determining the association between the ASCVD 10-year risk and dietary patterns, logistic regression was used to obtain multivariate-adjusted odds ratio and two-sided 95% CI (for ASCVD risk) and also linear regression (CAG analysis). Multicollinearity was tested using the variance inflation factor. Interaction terms were tested to evaluate presence of effect modification and all models were adjusted for potential covariates. For testing the trend analysis across quintiles of dietary pattern scores, the median score of each of the quintiles to the corresponding quintile were assigned. Linear regression adjusting for potential covariates was used to determine the association of CAG and dietary patterns. The varimax rotation produces uncorrelated factors, thus these patterns can be as continuous factors in models and adjust for their intake. This is due to the fact that an individual has a score for all dietary patterns. Weighting and bootstrapping calculations provided nationally representative results.

8.4. Results

8.4.1. Ten-year Atherosclerotic Cardiovascular Disease Risk and Vascular Age-gap Across Socio-demographic and Lifestyle Characteristics of Canadians 40-79 Years

Our results, using CHMS combined Cycles 1 and 2 (representative of 13,655,671 Canadians 40-79y (males= 48%, mean age=55y) indicated that Canadian adults aged 40-79y had a 10-year ASCVD estimated mean risk of 6.9%. Furthermore, 29% of this population had a high 10-year ASCVD risk. A significantly higher 10-year ASCVD risk was seen among groups that were older (50-79y), males, less than secondary level educated, in the lowest level of income and smokers compared to younger ages (40-49 years, $p < 0.0001$), females ($p<0.0001$), higher education levels ($p= <0.0001$), highest-income levels (0.043) and non-smokers ($p=0.027$), respectively (indicated in Table 8.1).

Regarding the mean prevalence of 10-year ASCVD risk and CAG across metabolic and medication factors, we found significant differences for all variables except for the ASCVD risk of people with reduced and not reduced HDL-C level which was not significantly different.

8.4.2. Dietary Patterns Analysis

The factor loadings of the corresponding dietary patterns are indicated in Table 8.2. The first dietary pattern was called the “Healthy like” dietary pattern with positive loadings of fruits, nuts, yoghurt, spinach and “other vegetables” and negative loadings of sausage and sport drinks.
The second dietary pattern was called the “Fast food” dietary pattern with positive loadings of chips, French/home/hash brown fries, diet drinks, hotdogs, red meat, and soft drinks. The third dietary pattern named the “Salad, greens cheese and condiments”, which is positively loaded by lettuce/green vegetables, tomato/tomato sauce, salad dressing/mayonnaise, and cheese. Finally,

the fourth dietary pattern named the "high carbohydrate and protein" pattern was positively loaded by baked/boiled, mashed potatoes, red meat, sausage, egg and ice-cream/frozen yoghurt.

8.4.3. Association Between Outcomes and Dietary Patterns

We found a significant adverse association between the "High carbohydrate and protein" dietary pattern and 10-year ASCVD risk for Canadians 40-79 years of age (P_{trend}= 0.013) (Table 8.3), after adjusting for potential covariates. The association between 10-year ASCVD risk and any other dietary pattern was not significant ($p>0.05$).

Further analysis of the "High carbohydrate and protein" dietary pattern score quantiles across socio-demographic factors revealed that the prevalence of non-immigrants (Q1 vs Q4:p=0.03; Q1 vs. Q5:p=0.011) and "Whites" (Q1 vs. Q4:p=0.007; Q1 vs. Q5:p=0.034) was significantly higher in the first quintile compared to the fourth and fifth quantiles of this dietary pattern. No significant difference was observed across quantiles of these dietary pattern scores for smokers; groups with the lowest level of education; physically inactive groups and individuals in the lowest income level (data not shown).

Our results showed that after adjusting for covariates, for every unit increase in the dietary factor scores of the "Healthy" dietary pattern, vascular age was two years younger than chronological age ($p<0.0001$). In addition, for each unit increase of the "Fast food" dietary pattern, the vascular age was on average 1.34 years older than the chronological age ($p=0.005$). Other dietary patterns were not significantly associated with CAG for this population ($p>0.05$).

Table 8. 1. Mean 10-year atherosclerotic cardiovascular disease risk and vascular age-gap across different factors

	10-y estimated ASCVD risk mean % ± SE (95% CI)	**P-value**	**CAG estimated mean % ± SE (95% CI)**	**P-value**
Total (40-79y)	6.91 ± 0.22 (6.46-7.36)		1.76+0.53 (-2.84--0.67)	
Socio-demographic and lifestyle factors				
Age by 10 years (y)				
40-49y*	2.1 ± 0.16 (1.76-2.44)		1.39 ± 0.62 (0.1-2.68)	
50-59y	5.09 ± 0.39 (4.29-5.9)	**<0.0001**	-2.75 ± 1.16 (-5.15-(-0.35))	**0.007**
60-69y	10.36 ± 0.35 (9.64-11.08)	**<0.0001**	-3.63 ± 0.72 (-5.12-(-2.14))	**<0.0001**
70-79y	26.29 ± 0.98 (24.28-28.3)	**<0.0001**	-7.68 ± 1.1 (-9.95-(-5.4))	**<0.0001**
Sex				
Male*	9.08 ± 0.34 (8.38-9.79)		-4.11 ± 0.61 (-5.37-(-2.84))	
Female	4.9 ± 0.24 (4.4-5.4)	**<0.0001**	0.42 ± 0.67 (-0.95-1.8)	**<0.0001**
An immediate family member having the premature cardiovascular disease				

Yes*	6.46 ± 0.36 (5.71-7.22)		-3.08 ± 0.86 (-4.86-(-1.29))	
No	6.94 ± 0.24 (6.45-7.44)	0.233	-1.02 ± 0.45 (-1.94--0.1)	**0.008**
Education level				
Less than secondary*	13.35 ± 1.21 (10.86-15.84)		-6.84 ± 1.18 (-9.28-(-4.39))	
Secondary	7.43 ± 0.71 (5.96-8.9)	**<0.0001**	-3.66 ± 1.55 (-6.86-(-0.46))	0.128
Other post-secondary	6.02 ± 0.77 (4.43-7.62)	**<0.0001**	-1.14 ± 1.91 (-5.09-2.81)	**0.025**
Post-sec graduate level	6.14 ± 0.29 (5.54-6.74)	**<0.0001**	-0.67 ± 0.51 (-1.73-0.38)	**<0.0001**
Income level				
Lowest-income*	8.71 ± 1.48 (5.65-11.77)		-6.33 ± 1.73 (-9.9-(-2.76))	
Lower middle income	8.53 ± 0.73 (7.02-10.04)	0.913	-3.83 ± 1.33 (-6.57-(-1.08))	0.896
Upper middle income	8.33 ± 0.47 (7.36-9.31)	0.811	-3.41 ± 0.88 (-5.22-(-1.6))	0.778
Highest income	5.48 ± 0.27 (4.92-6.03)	**0.043**	0.12 ± 0.49 (-0.9-1.14)	**0.047**
Having a family doctor				
Yes*	7.08 ± 0.24 (6.58-7.57)		-1.68 ± 0.56 (-2.83-(-0.54))	
No	5.57 ± 0.65 (4.23-6.92)	0.054	-2.33 ± 1.3 (-5.02-0.37)	0.64
Physical activity				
Active*	6.22 ± 0.52 (5.15-7.29)		0.77 ± 0.86 (-1.01-2.54)	
Moderately active	6.7 ± 0.42 (5.84-7.56)	0.531	0.53 ± 0.66 (-0.84-1.9)	0.823

In-active	7.3 ± 0.31 (6.67-7.93)	0.082	-3.84 ± 0.66 (-5.2-(-2.48))	**<0.0001**
Smoking status				
Non-smoker*	6.56 ± 0.25 (6.03-7.08)		0.7 ± 0.44 (-0.21-1.61)	
Smoker	8.22 ± 0.6 (6.97-9.46)	**0.027**	-10.75 ± 1.09 (-13-(-8.51))	**<0.0001**
Drinking alcohol				
Ever*	6.89 ± 0.28 (6.3-7.48)		-1.73 ± 0.61 (-2.99-(-0.48))	
Never	7.02 ± 0.66 (5.66-8.37)	0.878	-1.87 ± 1 (-3.94-0.2)	0.911
Metabolic and medication use				
Having at least 1 MetS component				
Yes*	8.64 ± 0.27 (8.09-9.2)		-5.49 ± 0.65 (-6.83-(-4.16))	
No	2.83 ± 0.19 (2.44-3.22)	**<0.0001**	7.05 ± 0.28 (6.48-7.62)	**<0.0001**
Having at least 2 MetS components				
Yes*	10.59 ± 0.39 (9.78-11.4)		-9.14 ± 0.71 (-10.61-(-7.67))	
No	4.09 ± 0.18 (3.72-4.46)	**<0.0001**	3.91 ± 0.4 (3.08-4.74)	**<0.0001**
Having at least 3 MetS components				
Yes*	13.54 ± 0.93 (11.63-15.45)		-13.36 ± 0.95 (-15.32-(-11.39))	
No	5.39 ± 0.23 (4.9-5.87)	**<0.0001**	0.91 ± 0.46 (-0.03-1.86)	**<0.0001**

Having at least 4 MetS components				
Yes*	16.08 ± 1.44 (13.11-19.04)		-21.01 ± 1.78 (-24.69-(-17.33))	
No	6.43 ± 0.24 (5.95-6.92)	**<0.0001**	-0.75 ± 0.5 (-1.78-0.28)	**<0.0001**
Abdominal obesity				
Yes*	8.32 ± 0.46 (7.37-9.27)		-5.4 ± 0.8 (-7.06-(-3.74))	
No	5.75 ± 0.36 (5.02-6.49)	**0.001**	1.24 ± 0.55 (0.11-2.37)	**<0.0001**
Reduced high-density lipoprotein cholesterol level				
Yes*	7.79 ± 0.47 (6.82-8.76)		-7.17 ± 0.84 (-8.9-(-5.45))	
No	6.59 ± 0.28 (6.02-7.16)	0.056	0.25 ± 0.5 (-0.78-1.28)	**<0.0001**
Elevated triglycerides levels				
Yes*	9.16 ± 0.43 (8.26-10.06)	**<0.0001**	-9.27 ± 0.92 (-11.17-(-7.37))	**<0.0001**
No	6.02 ± 0.31 (5.38-6.65)		1.24 ± 0.56 (0.08-2.39)	
Elevated fasting plasma glucose				
Yes*	12.13 ± 0.57 (10.95-13.31)	**<0.0001**	-9.49 ± 0.99 (-11.53-(-7.45))	**<0.0001**
No	5.06 ± 0.22 (4.6-5.52)		0.98 ± 0.42 (0.11-1.86)	
Elevated blood pressure				

	Yes*	11.88 ± 0.37 (11.11-12.64)		-10.13 ± 0.74 (-11.67-(-8.6))	
	No	3.92 ± 0.14 (3.62-4.22)	**<0.0001**	3.29 ± 0.47 (2.33-4.25)	**<0.0001**
	Antihypertensive medication use				
	Yes*	14.07 ± 0.58 (12.88-15.25)		-11.55 ± 0.86 (-13.33-(-9.77))	
	No	4.74 ± 0.18 (4.38-5.11)	**<0.0001**	1.21 ± 0.51 (0.16-2.26)	**<0.0001**
	Lipid-lowering medication use				
	Yes*	14.37 ± 0.76 (12.81-15.94)		-7.83 ± 1.43 (-10.79-(-4.88))	
	No	5.59 ± 0.23 (5.11-6.06)	**<0.0001**	-0.68 ± 0.57 (-1.85-0.5)	**<0.0001**

ASCVD, atherosclerotic cardiovascular disease; CI, two-sided confidence interval; MetS, metabolic syndrome, defined as the presence of at least three out of the following five factors: elevated triglycerides level (1.7 mmol/L), reduced high-density lipoprotein cholesterol level (1.0 mmol/L for men and 1.3 mmol/L for women), elevated blood pressure (systolic blood pressure ≥ 130 and/or diastolic ≥ 85mmHg) and/or diagnosis by health professional and elevated fasting plasma glucose level (≥ 5.6 mmol/L); SE: standard error; y: years.

*Reference level. Alpha=0.05 significant level.

Table 8. 2. Factor loadings from principal components analysis of dietary intakes of the 40-79 year-old study population of Study 5

Food/Food groups	Dietary patterns emerged			
	Factor 1*	Factor 2	Factor 3	Factor 4
Other Vegetables	0.67	.	.	.
Fruit	0.56	.	.	.
Nuts	0.48	.	.	.
Yogurt	0.30	.	0.21	.
Sport Drinks	-0.30	.	.	.
Chips	.	0.66	.	.
French/home fries/hash brown potatoes	.	0.66	.	.
Diet Drinks	.	0.54	.	.
Hot Dogs	-0.22	0.43	.	.
Lettuce/Green vegetables	0.25	.	0.73	.
Salad Dressing/Mayonnaise	.	.	0.71	.
Tomato and tomato Sauce	.	.	0.50	.
Milk	.	.	.	.
Cereal	.	.	.	.
Baked/Boiled/mashed Potatoes	.	.	.	0.61
Red Meat	.	0.31	.	0.56
Sausage	-0.33	0.24	.	0.52
Eggs	.	.	.	0.47
Rice	0.20	.	-0.22	.
Pasta	.	0.25	.	.
Beans	.	.	.	.
Spinach	0.31	.	0.28	.
White Bread	.	.	.	.
Ice-cream/Frozen Yogurt	.	.	.	0.30
Brown Bread	.	.	.	.
Organ meat	.	.	.	.
Liver	.	.	.	.
Soft Drinks	.	0.30	.	.
Flavored Drinks	.	.	.	.
Cheese	-0.23	.	0.30	.
Vegetable Juice	.	.	.	.
Fruit Juice	.	.	.	.

* Only factor loading scores between above 0.2 and below -0.2 are indicated in this table.

Table 8. 3. Multivariate-adjusted odds ratios for the association of 10-year atherosclerotic cardiovascular disease risk and dietary patterns prevalent among Canadians aged 40 to 79 years, Canadians Health Measures Survey combined Cycles 1 and 2, 2007-11 (representative of 26,038,108 Canadians aged 40 to 79 years).

	Q1	Q2	Q3	Q4	Q5	P-trend*	Continues factor scores (CI)†	P-value
				Odds ratio (upper 95% confidence interval-lower confidence interval)				
10-year atherosclerotic cardiovascular disease **risk (ages 40-79y)**‡								
"Healthy"	1	0.83 (0.51-1.36)	0.6 (0.34-1.07)	0.76 (0.42-1.38)	0.68 (0.32-1.43)	0.3248	0.87 (0.61-1.22)	0.4094
"Fast food"	1	0.9 (0.53-1.52)	0.4 (0.26-0.62)	0.64 (0.29-1.39)	0.55 (0.29-1.05)	0.1305	0.86 (0.66-1.12)	0.2537
" Salad, greens, cheese and condiments "	1	1.25 (0.63-2.51)	1.1 (0.6-2.02)	1.06 (0.51-2.2)	1.03 (0.58-1.84)	0.8565	0.92 (0.76-1.12)	0.3935
"High carbohydrate and protein"	1	1.24 (0.7-2.21)	0.93 (0.49-1.75)	1.45 (0.84-2.54)	1.87 (1.07-3.28)	**0.0128**	1.43 (1.19-1.72)	**0.0001**

ASCVD, atherosclerotic cardiovascular diseases; Q, Quintile; y,year

* For testing the trend analysis across quantiles of dietary pattern scores, we assigned the median score of each of the quintiles to the corresponding quantile.

† The continues factor scores were used in multivariate analysis logistic regression.

‡ Model adjusted for income, education, physical activity, alcohol intake, body mass index and other dietary patterns between 1-4

8.5. Discussion

The mean 10-year ASCVD risk of 40-79 years olds was 6.9%, with almost one-third of this population having a high risk of 10-year ASCVD. Our results indicate that for Canadian males 40-79 years, their cardiovascular system is aging on average 4 years more than their chronological age, but females' cardiovascular systems are aging at a similar rate to their chronological age. Dietary patterns seemed to make a significant difference in the risk of ASCVD and CAG.

Our result of the 10-year ASCVD risk (6.9 %) were similar to the results from Anderson et al.[15] (6.6 %), with only a small difference likely due to the study population age range difference (40-75 years for the latter study). The analysis of CAG for U.S. adults 30-75y revealed that male and female cardiovascular system are aging 7.8 and 5.4 years more, respectively, than their chronological age (Yang et al., 2015). The CAG reported in the U.S. was larger compared to our study. These researchers have indicated the non-laboratory risk factor equations, which they used in their study gives larger CAG's compared to the laboratory-based risk factor equations used in the present study.

In this study, we found those with and without MetS had a mean 10-y ASCVD risk of 13.54% and 5.39%, respectively. These results are consistent with the concept of MetS, which indicates the risk of CVD is two times higher for those with MetS compared to those with no MetS (Alberti et al., 2009).

We found the "high carbohydrate and protein" dietary pattern to significantly increase the risk of CVD. This dietary pattern which is loaded with high intakes of baked/boiled/mashed potatoes, red meat, sausage, eggs and ice-cream/frozen yoghurt was similar to the "Western" dietary pattern, which has been found to have a positive association with many chronic diseases (Movassagh & Vatanparast, 2017a, 2017b). The significantly greater prevalence of "White" and "non-immigrant" groups in the highest quintiles of this dietary pattern intake score may indicate that this dietary pattern could be a traditional Canadian dietary pattern. In agreement with our results, the Multi-Ethnic Study of Atherosclerosis (Nettleton, Polak, Tracy, Burke, & Jacobs, 2009), the Health Professionals Follow-up Study (Hu et al., 2000) and the Nurses' Health Study (Fung et al., 2004) found similar dietary patterns to increase the risk of CVD and its risk factors cross-sectionally (Nettleton et al., 2009) and prospectively among the U.S. population. The foods that had a positive loading on this dietary pattern in our study have previously been shown to adversely affect CVD risk (Adlercreutz, 1990; Deshmukh-Taskar et al., 2009; Study, 2015). The processed foods and foods with a high glycemic index have been shown to contribute to the development of ASCVD.

Our finding for ASCVD risk assessment and CAG were similar in most part. However, the CAG results were more interpretable compared to ASCVD findings. For example, the 10-year ASCVD risk for smokers was 8.22% and for non-smokers was 6.56%; however, the CAG for smokers was 10 years older than non-smokers.

The present study had some limitations. One limitation was the absence of a few foods from FFQ used by CHMS, especially from grains and meat and alternative groups. Secondly, our study design was cross-sectional. Thus results should be interpreted with caution and do not imply causation. In addition, despite the usefulness of PCA method for generating dietary patterns, these a posteriori methods have low reproducibility (Moeller et al., 2007) due to the research-based decisions made through the analysis and the specifics of the population.

8.6. Conclusion

Our study is the first in Canada to investigate the prevalence of 10-year ASCVD risk and CAG of Canadians 40-79y and their association with dietary patterns. To obtain our results, we used CHMS data that included blood measurements for a large representative sample of Canadians. Observing an association between CAG and "Healthy" and "Fast food" dietary patterns, we would suggest long-term prospective studies of dietary interventions.

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CHAPTER 9: General Discussion

Prevention is key to reducing the burden of non-communicable diseases including diabetes and CVD on the individual, society and healthcare sector (Punthakee, Goldenberg, & Katz, 2018). In order to prevent these diseases, identifying people at high risk and using modifiable factors in the prevention of these diseases are the priority. The MetS, CVD risk, and CAG are concepts, which have been recommended by national health organizations for identifying individuals with high risk of developing these diseases (Anderson et al., 2016; Punthakee et al., 2018)

Diet has been recognized as an important modifiable factor in the prevention of metabolic disorders, diabetes and CVD (Goff et al., 2014; Mente, de Koning, Shannon, & Anand, 2009; Punthakee et al., 2018; Wilson, McIntyre, & Nicolosi, 2001). The aim of this thesis was to determine the association of diet with MetS, diabetes, CVD, and CAG among Canadians. To our knowledge, no studies have addressed these objectives for all of the Canadian population.

As the first step, a scoping review using the methodology presented by (Arksey & O'Malley, 2005) was conducted to understand the gaps in the literature regarding the association of MetS and dietary patterns. A total of 39 studies were included in our scoping review from 23 different countries around the world, which have investigated this association among their populations (Hosseini, Whiting, & Vatanparast, 2016). Based on this scoping review, most studies included used factor analysis method and the a priori dietary approach. In addition, the methodological approach for evaluating the dietary pattern should be chosen based on the research question and objective. The main finding of this study was that following the Mediterranean dietary pattern reduced the risk of MetS, while following a "Western" pattern increased risk of MetS. Further, this association had not been evaluated between Canadian adolescent and/or adults. These findings were beneficial in choosing the objective and methodology of Study 4 and 5.

At the present time, the only available national survey in Canada, which includes direct health measurements and dietary intake data, is the CHMS. Thus, Study 2 was designed to determine the dietary intake of Canadians from foods/food groups and across different levels of socio-demographics. The CHMS dietary intake data from Vegetables and Fruit and from Milk

Products groups were complete compared to data from CCHS 2.2. For the food groups of Grains and Meat and alternatives, a few foods were not included in the CHMS FFQ. However, food intake patterns with regards to across age, sex and income showed similarities to the literature. These results showed that CHMS dietary intake data are useful for determining the association of diet and health outcomes for Canadians using a dietary pattern approach.

Prior to investigating the association of MetS, CVD and CAG with dietary patterns, it was necessary to determine the characteristics of individuals with diagnosed diabetes, undetected diabetes, and pre-diabetes. Therefore, in Study 3, the prevalence of diabetes (diagnosed and undetected and pre-diabetes) was determined across levels of socio-demographic and lifestyle factors. Also, the dietary intake of people with diagnosed diabetes and the rest of the population were determined and compared, as this group represented people who may have been influenced, a priori in their selection of foods and beverages. The results showed that prediabetes prevalence was 12.4% among 20-79 year old Canadians. Further, 37.3% of those that had diabetes (7.5%) were undiagnosed. In addition, the results of this study showed that diagnosed diabetes individuals had fewer intakes from juice and ice-cream and more intake from potatoes and diet soft drinks compared to other groups. This finding was helpful in determining the study population of Study 4 and 5.

Finally, in Study 4 and Study 5, the prevalence of MetS, CVD risk, and CAG were determined across different socio-demographic and lifestyle levels and also their associations with dietary patterns were investigated. Results of Study 4 indicated that the MetS prevalence was 16.9% among Canadians aged 12 to 79 years. In addition, the "Fast food" dietary pattern with positive loadings of hotdogs, sausage/bacon, chips, fries, and diet soft drinks was associated with increased risk of MetS (odds ratio=1.26; (95% CI: 1.016 to 1.55; p=0.035). In Study 5, the mean 10-year ASCVD risk was reported 6.9% (representative of 13,655,671 Canadians aged 40-79 years). The mean CAG for men was -4.1 years (older) and for females was +0.4 years (younger). In addition, these results showed that the "High carbohydrate and protein" dietary pattern, which included non-fried potatoes, red meat, sausage, egg and ice-cream/frozen yoghurt was adversely associated with 10-year ASCVD risk ($P_{\text{-trend}}$= 0.0128). The "Healthy" and "Fast food" dietary patterns had an inverse (p<0.0001) and direct (p=0.005) association, respectively, with CAG adjusted for potential covariates.

Overall, diet was identified as an important factor that may prevent and develop the aforementioned outcomes. However, further investigation is required to understand this association among different sociodemographic groups of the population.

9.1. Dietary intake: Food Group and Dietary Patterns

For investigating dietary intake, food groups and dietary pattern analysis were primary to Studies 2 to 5. In Study 2, this involved the intake of Canadians aged 6-79 years from different food groups and across sociodemographic factors. Canadians were having 1.62, 1.64, 4.33 , 2.17, 0.47, 0.47, 0.14 and 0.7 serving/day from Meat and Alternatives; Milk Products; Vegetables and Fruit; Grain Products; dietary fat; SSB; diet drinks; and fruit and vegetable juice, respectively. Comparing the intake data of the four main food groups from CHMS with data reported from CCHS 2.2 (Garriguet, 2007), the total intakes from Milk Products and from Vegetables and Fruit were similar. Regarding the Meat and Alternatives and Grain Products intakes, fewer servings were reported in CHMS (1.62 and 2.17 servings/day, respectively, $p< 0.05$) compared to CCHS 2.2 (2.04-2.71 and 6.41-5.64 servings/day, respectively, $p< 0.05$ (Garriguet, 2007). In addition, Canadians dietary intake was different across different levels of sex, age, income, education, and physical activity. Based on these results, a list of foods deemed beneficial to add to the FFQ (CHMS user guide) in order to have a comprehensive FFQ was generated, especially those having direct health effects in the CHMS data set.

For choosing the type of dietary pattern analytical method, results from the Scoping review (Study 1) and also research questions, data available and outcomes of the studies were considered. In Study 1, 39 studies were included and classified to two groups based on whether they had used a priori or a posteriori methods. The researchers of these studies mostly used the factor analysis method such as the PCA method to extract their dietary patterns. The reasons for using such method among those researchers were not determined directly in the articles. However, these studies were all population-based studies, which they aimed to determine the prevalent dietary patterns among their study population (Moeller et al., 2007; Tucker, 2010). Thus, a method such as the PCA would have been most beneficial in addressing their objectives compared to other methods, which include intermediate factors and extract patterns that do not only explain the variation in the diet such as the PLS or the RRR method (Hoffmann, Schulze, Schienkiewitz, Nöthlings, & Boeing, 2004).

In Study 4 and 5, the PCA method was used for two main reasons, first similar to studies included in the scoping review, the diet among the study population was aimed to be determined.

Second, a multifactorial outcome would make the choice of intermediate factors and interpretation of the dietary patterns extracted challenging. The PCA dietary extraction method used in Study 4 and 5 of this thesis extracted dietary patterns that were named based on their factor loadings on the pattern (Moeller et al., 2007). The dietary patterns were named the “Healthy like” and also the unhealthy dietary patterns that included, “Western”, “Fast food”, “High carbohydrate and protein” dietary patterns. Similarly, these dietary patterns were found in other research conducted in Korea (Cho, Shin, Lim, & Kim, 2011), Mexico (Denova-Gutiérrez et al., 2010), U.S. (Lutsey, Steffen, & Stevens, 2008), Iran (Esmaillzadeh et al., 2006), Japan (Akter, Nanri, Pham, Kurotani, & Mizoue, 2013) and Germany (Heidenberger & Stummer, 1999) (Barbaresko et al., 2014).

9.2. Health Outcomes in Canada

In this thesis, diabetes, MetS, CVD risk, and CAG were investigated among Canadians. The prevalence of diagnosed diabetes, undetected diabetes, and pre-diabetes among Canadians 20-79 years were 4.7, 2.8 and 12.4%. For the analysis, we used the HbA1c measurements to determine this prevalence, first, due to having a larger sample size if we used the non-fasting CHMS data compared to the fasting data which had almost half the sample size. In addition, based on the literature, HbA1c is a better predictor for CVD risk and for the Canadian population it does not underestimate the prevalence of diabetes (Punthakee et al., 2018). This made the blood sugar evaluation method appropriate for the objectives of our study.

These findings have important public health messages. There are disease management plans for those who are diagnosed with type 2 diabetes, and early diagnoses is highly beneficial especially for preventing and delaying microvascular complications (Pratley, 2013). Results of Study 6 showed that 2.8%, which are representative of 644,640 Canadians 20-79y have diabetes and are not aware of their disease status. In addition, the pre-diabetes state is a reversible state for at least 30% of those with pre-diabetes (Nathan et al., 2007; Perreault & Færch, 2014). Our results for pre-diabetes (12,4%) which are representative of 6,909,867 Canadians that have prediabetes and 30% of this group would be 856,460 Canadians that have the chance to reverse to a normal state with lifestyle modification. These findings have important public health implications for screening, lifestyle modifying interventions among the high-risk populations.

The prevalence of MetS among 12-79 years old Canadians was 16.9 percent with abdominal obesity being the most prevalent component among this population. Further, almost two in every three Canadians have at least one component of the MetS present. In the U.S., similarly, abdominal obesity had the highest prevalence among other all components of MetS (Beltrán-Sánchez, Harhay, Harhay, & McElligott, 2013). Abdominal obesity is known to be one main contributor of the MetS pathophysiology (Després & Lemieux, 2006; Grundy, 2016) and it is known that there is a high chance of the third MetS component coming along when there are already two components present (Alberti et al., 2009).

The findings of the scoping review in Chapter 3 showed that only two studies have included adolescents as their study population. This could be due to the low prevalence of MetS among adolescents and the sample size and power of the analysis. Further, a unique criterion for the MetS is not yet determined. These were a few challenges in our Study 4 analysis. However, based on the prevalence of 12.7% for abdominal obesity and the impact it has on the MetS status, public health educational intervention should be considered especially in schools and high schools. As well, based on the CHMS direct health measures data available, determining age-sex specific percentiles for each of the MetS components for Canadian adolescents should be considered for future studies.

The ASCVD risk of Canadians using the 2013 ACC/AHA risk assessment document, which provided sex and ethnic-specific equations showed a mean risk of 6.9 % for Canadians 40-79 years of age. In addition, almost 29% of the Canadian population aged 40-79 years was at high risk for ASCVD in the next 10 years. It is important for studies conducted in Canada as a multi-ethnic country to have ethno-specific risk assessment tools. However, this risk assessment tool is only considering a separate equation for African Americans, which are one of the many ethnic groups residing in Canada. Based on the importance of ethnic variability for the risk factors of CVD, clinical longitudinal studies on major ethnicities residing in Canada to investigate the ethnic-specific cutoffs for different risk factors similar to what is available for waist circumference (Alberti et al., 2009) is suggested.

Overestimation of risk assessment tools and has been discussed among researchers as a limitation (Ridker & Cook, 2013) of the 2013 ACC/AHA proposed tool (Goff et al., 2014). However, in Canada, the approach presented by CCS Guidelines (Anderson et al., 2016), which indicates using the Framingham risk assessment equation, and multiplying the risk by a factor of two for those having an immediate family member with premature CVD was compared with the pooled cohort approach in terms of statin therapy requirement. The results of the latter study, which indeed has a similar co-author to CCSG guidelines document (Anderson et al., 2016), indicate that a similar number of people would be starting statin-therapy using the two latter approaches for risk assessment in Canada (Hennessy, Bushnik, Manuel, & Anderson, 2015).

For the first time, the CAG for Canadians 40-79 years old was determined in Study 5 based on sex-specific “Heart age” sheets (D’Agostino et al., 2008). The Diabetes Canada ((Punthakee et al., 2018) guidelines and CCS Guidelines (Anderson et al., 2016) have recommended using this concept for identifying populations at high risk in addition Diabetes Canada ((Punthakee et al., 2018) to or superior to (Anderson et al., 2016) the conventional risk assessment tools. The aim of CAG was to make the CVD risk conversation more meaningful especially for those with lower short-term and higher long-term risk including younger ages and women (Anderson et al., 2016) . This is in agreement with results of Study 5 when evaluating the mean of the 10-year ASCVD risk and CAG, side by side, across different factors.

Our findings indicate that on average, males’ vascular system is aging faster than females with the same age. This is in agreement with the finding from a Canadian follow-up study on diabetic patients where they found that males move to the high-risk CVD category at age 48 and females move when they reach the age of 54 (Booth, Kapral, Fung, & Tu, 2006) . Although still unclear, two factors that are believed to be a possible explanation to the increased risk of CVD at younger ages for males compared to female are their hormonal differences and susceptibility to oxidative stress (Kander, Cui, & Liu, 2017). This difference is the reason for having two separate risk assessment equations for males and females (Goff et al., 2014).

9.3. Association of Outcome and Dietary Patterns

Scoping review (Study1) summarized the studies that investigated the association of MetS and dietary patterns. Based on the results, most studies, which had extracted a “Western” dietary pattern characterized by high intakes of nutrient-empty and calorie-dense foods had found a significant direct association with MetS. The foods that had loadings on this dietary pattern included red/processed meat, fast food, refined grains/cereals, SSB, eggs, sweets/desserts (positive loading) and fruit and vegetables, and dairy products (negative loading). In addition, a “Healthy” dietary pattern did not show a significant association with MetS in most studies, which could be due to not being as “healthy” as required for such an outcome. Since the studies looking into the more than just “healthy”, but a “heart healthy” dietary pattern such as the Mediterranean dietary pattern did show to have a significant association with MetS. In Study 4 and 5, the associations of Mets, 10-year ASCVD risk and CAG and dietary patterns was evaluated for the Canadian population. Analogously, in Study 4, results indicated that the “Fast food” pattern had an inverse association with MetS. However, the “Healthy like” dietary patterns did not show to have an association with MetS. Similarly, in Study 5, when assessing the ASCVD risk as an outcome, again the “Healthy like” dietary pattern was not associated significantly with ASCVD, controlling for covariates, but the “High carbohydrate and protein” pattern with positive factor loading of baked/boiled/mashed potatoes, red meat, sausage, eggs and ice-cream/frozen yoghurt did show to have an inverse association with 10-year ASCVD risk. These findings are similar to what was observed among the population-based studies included in this scoping review. These results could indicate the importance of preventing an unhealthy dietary pattern. As well, for finding better results, a step ahead of the “healthy” dietary pattern should be taken with a focus on “heart healthy” nutrients and minerals which are included in dietary patterns such as the Mediterranean diet (Eckel et al., 2014). However, the results for the analysis of the association between CAG and dietary patterns revealed that with each unit increase in the “Healthy” dietary pattern and “Fast food” dietary pattern, the vascular age was two years younger and 1.34 years older, respectively than the chronological age. The reason to finding an association between the CAG and “Healthy” dietary pattern but not with ASCVD risk, could be due to the type of outcome. The CAG was a continuous outcome with a unit of 1 year. However the 10-year ASCVD risk was a dichotomous (high risk vs. low risk) outcome.

In Study 4, another finding was that no significant association was observed among the younger individuals regarding MetS status and dietary patterns. Not finding a high prevalence of this syndrome among this population due to a young age could be one reason (Setayeshgar, Whiting, & Vatanparast, 2012). In addition, in Study 2 we found that adolescents tend to have more SSB and dietary fat from sources such as fries and chips, which could be a surrogate for a less healthy diet. Therefore, MetS not appearing yet in this age group that have a less healthy diet overall, in a cross-sectional designed study it seems, as if this population is having an unhealthy diet and a very low prevalence of MetS, which could possibly be the reason for not finding the significant association in this age group. These results warrant more focus on the younger ages, which the association is not apparent, especially when we see that dietary pattern continues to adulthood (Movassagh, Baxter-Jones, Kontulainen, Whiting and Vatanparast, 2017).

These results are important in terms of policy implications in the area of Nutrition and

CVD health in Canada. Further prospective studies are required to assess the adequacy of recommendations by Canada's Food Guide in terms of chronic diseases, the potential adherence to the Mediterranean dietary patterns and the effect of such diet on the Canadian population health.

9.4. Strengths and Limitations

The studies of this thesis had many strengths related to the data, methods and study results. First, the CHMS nationally representative survey is the only survey at the present time, which includes several direct health measures and dietary intake data for ages 3-79 years. We have for the first time reported the CAG in Canada and have presented a comprehensive picture of ASCVD risk and CAG across different sociodemographic and lifestyle factors next to each other, which is important for public health awareness and health implication. In addition, the association between cardiometabolic outcomes including MetS, 10-year ASCVD risk, and CAG and dietary patterns have been investigated at the population level adjusting for covariates among Canadian adults. The dietary pattern approach used (PCA) in Study 4 and 5 was a superior method to the conventional single nutrients' method for outcomes of this thesis with an unclear pathophysiological process.

The studies of this thesis had many limitations. One limitation of the CHMS data sets were the discordance of Cycle 3 data with Cycles 1 & 2 data, that did not allow combing the three cycles together for increasing the sample size and analytical power of our studies. Therefore, for a few variables such as ethnicity and alcohol intake results could not be published due to small sample size in one or more cells. In addition, the food items that were not included in the CHMS FFQ were another limitation. The cross-sectional design of CHMS implies that interpretation of results should not indicate any causational relationships between the study variables and outcomes. Furthermore, the PCA method we used, despite the several strengths, has a limited reproducibility.

9.5. Future Studies

The results of dietary patterns extracted in this thesis warrant further investigations among the different levels of socio-demographic factors. In Canada, a multi-ethnic country, dietary pattern investigations among ethnicities would be beneficial for understanding the prevalent dietary patterns among them and promoting healthy dietary patterns such as the

Mediterranean diet for each ethnic group based on their specific

The CMHS data from different consecutive cycles are a unique data resource to define age- and sex-specific MetS percentile curves for Canadian adolescents.

Interventional studies considering objectives related to a modification in the status of diet, physical activity and smoking on groups in the lower income and education groups are recommended.

9.6. Conclusion

The findings of this research indicate the high prevalence of metabolic abnormalities, MetS, prediabetes, diabetes and eventually CVD in Canada, especially among low income and education level groups. We found that a dietary pattern that includes hotdogs, sausage/bacon, chips, fries, and diet soft drinks and a pattern highly loaded by baked/boiled, mashed potatoes, red meat, sausage, egg and ice-cream/frozen yoghurt were associated with increased risk for MetS and CVD after adjusting for potential covariates and BMI. Looking at the high prevalence among lower socioeconomic groups and the processed/fast food content of the dietary patterns extracted, the findings of this thesis suggest, the need for a public health initiative to reduce the rising prevalence of especially reversible metabolic abnormalities including MetS and prediabetes and eventually diabetes and CVD in the coming years. This study suggests a need for a multidimensional initiative at four main sites including media, healthcare, neighborhood, and education centers with a focus on a healthier balanced diet, increasing the physical activity and stop/preventing smoking.

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Appendix A

Table A. 1 MEDLINE and EMBASE search strategy and keywords/subject headings (general keywords related to the topic).

	Search subject-heading Term	Details
1	Metabolic Syndrome X/	Map Term to Subject Heading
2	(Metabolic adj Syndrome).mp.	[mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
3	MetSyn.mp.	[mp=title, abstract, original title, the name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
4	Insulin resistance syndrome.mp.	[mp=title, abstract, original title, the name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
5	1 or 2 or 3 or 4	
6	exp Diet/	Map Term to Subject Heading
7	"dietary pattern*".mp.	[mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
8	"diet* pattern*".mp.	[mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
9	(diet* adj3 pattern*).mp.	[mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
10	6 or 7 or 8 or 9	
11	5 and 10	
12	Limit 11 to (English language and humans and yr="2005 - 2014")	

Table A. 2 MEDLINE and EMBASE search strategy and keywords/subject headings (specific keywords related to the topic).

	Search subject-heading Term	Details
1	Metabolic Syndrome X/	Map Term to Subject Heading
2	(Metabolic adj Syndrome).mp.	[mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
3	MetSyn.mp.	[mp=title, abstract, original title, the name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
4	Insulin resistance syndrome.mp.	[mp=title, abstract, original title, the name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
5	1 or 2 or 3 or 4	
6	Dietary index.mp.	[mp=title, abstract, original title, the name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
7	Vegetarian diet.mp. or Diet, Vegetarian/	Map Term to Subject Heading
8	Dietary Guidelines for Americans Index.mp.	[mp=title, abstract, original title, the name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
9	Diet, Mediterranean/	Map Term to Subject Heading
10	DASH.mp.	
11	Mediterranean diet.mp.	[mp=title, abstract, original title, the name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
12	Mediterranean diet.mp. or exp Diet/	[mp=title, abstract, original title, the name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]

13	Healthy Eating Index.mp.	[mp=title, abstract, original title, the name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
14	Factor analysis.mp.	[mp=title, abstract, original title, the name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
15	Cluster analysis.mp.	[mp=title, abstract, original title, the name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]
16	6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15	
17	5 and 16	
18	Limit 17 to (English language and humans and yr="2005 - 2014")	

Appendix B

Additional results from principal component analysis for Study 4.

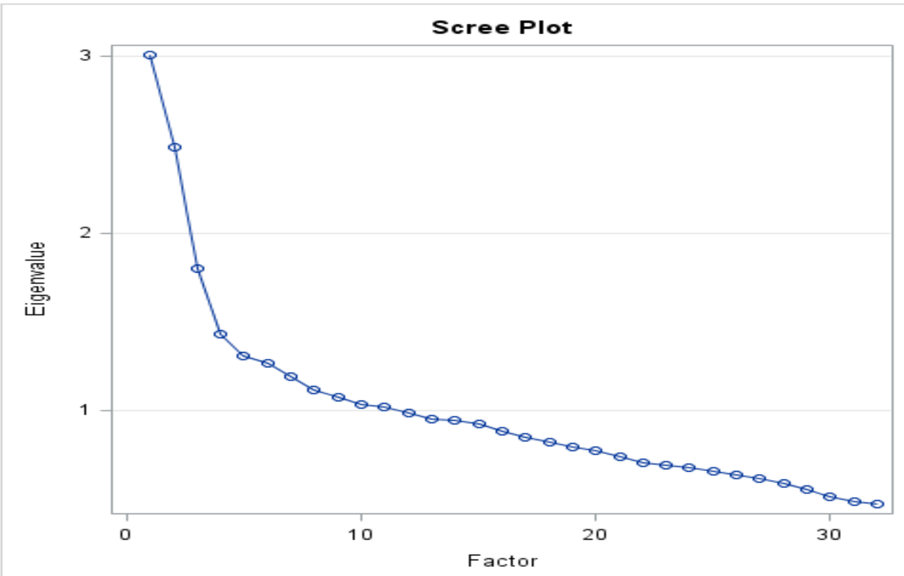

Figure B. 1. Scree plot results from the principal component analysis for ages 12-19y.

Table B. 1. Eigenvalue by each factor from principal component analysis for the prevalent dietary patterns among 20-50 year old Canadians.

	Eigenvalue	Difference
1	3.00627217	0.52061705
2	2.48565511	0.68474175
3	1.80091336	0.37313089
4	1.42778247	0.11949782
5	1.30828465	0.04054389
6	1.26774076	0.0740617
7	1.19367906	0.07904884
8	1.11463023	0.038871
9	1.07575922	0.03907595
10	1.03668327	0.01740051
11	1.01928277	0.03424818

Table B. 2**.** Orthogonal Transformation Matrix from principal component analysis for the prevalent dietary patterns among 20-50 year old Canadians.

Orthogonal Transformation Matrix										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	-0.49883	0.54622	0.38343	0.17681	-0.35659	0.08114	-0.19721	0.12928	0.28921	-0.03932
2	0.58178	0.23674	0.30379	0.25588	0.08478	0.43047	0.37011	0.16388	0.1918	0.23369
3	0.00537	-0.36575	0.1304	0.6421	-0.0343	-0.08667	0.05226	-0.45046	0.30463	-0.36023
4	-0.05774	0.30073	-0.64654	0.35588	0.41335	0.22161	-0.23601	0.19885	0.14854	-0.15585
5	0.28517	-0.2157	-0.1897	0.23496	-0.67401	0.2108	-0.37475	0.26894	-0.26232	-0.02564
6	0.22993	0.18874	0.08184	0.20489	0.01897	-0.7099	0.16439	0.47992	-0.1139	-0.29697
7	-0.11144	-0.38568	0.00347	-0.32573	-0.03702	0.24225	0.18457	0.48556	0.46761	-0.42914
8	0.24749	0.39341	-0.39719	-0.28565	-0.42174	-0.06692	0.29262	-0.38772	0.2186	-0.28026
9	0.44879	0.07405	0.2506	-0.27573	0.19196	-0.10506	-0.69103	-0.12198	0.29866	-0.15743
10	-0.00802	0.17389	0.24983	-0.05839	0.1513	0.35901	0.03197	-0.10176	-0.57208	-0.643

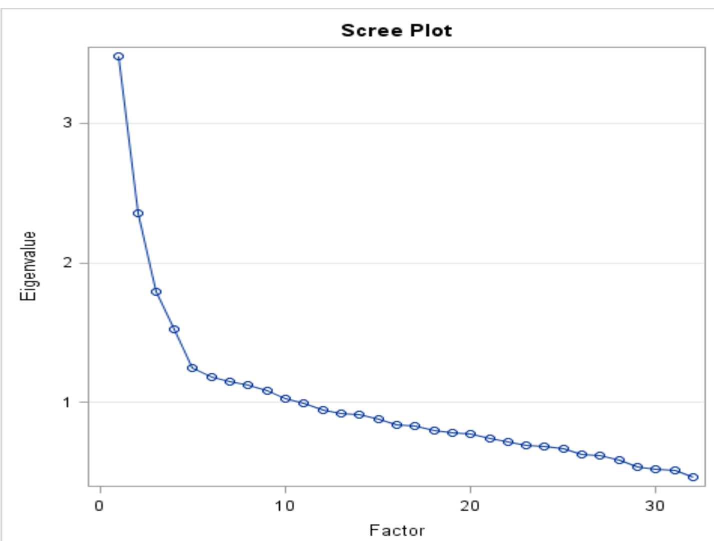

Figure B. 2. Scree plot results from the principal component analysis for ages 20-49y.

Table B. 3. Eigenvalue by each factor from principal component analysis for the prevalent dietary patterns among 20-50 year old Canadians.

	Eigenvalue	**Difference**

1	3.4794833	1.12880219
2	2.35068111	0.55421499
3	1.79646612	0.27556938
4	1.52089673	0.27414488
5	1.24675186	0.06883902
6	1.17791284	0.03006642
7	1.14784642	0.02695377
8	1.12089265	0.03531406
9	1.0855786	0.06043067
10	1.02514792	0.03053015
11	0.99461777	0.04725578

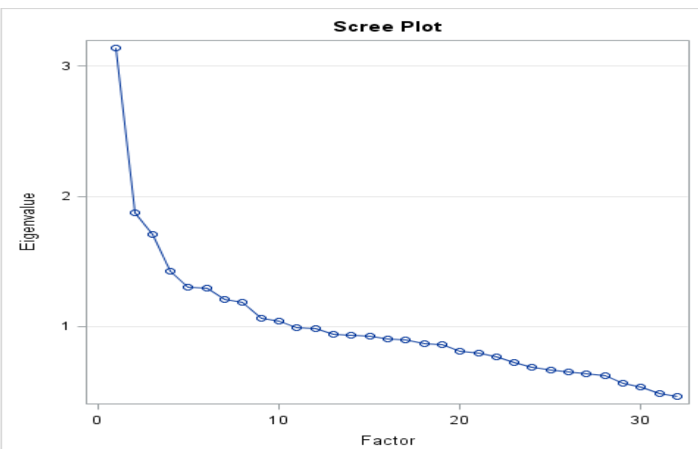

Figure B. 3. Scree plot results from the principal component analysis for Canadians aged 49 years and above.

Table B. 4. Eigenvalue by each factor from principal component analysis for the prevalent dietary patterns among 50-79 year old Canadians.

	Eigenvalue	Difference
1	3.13855815	1.26462869
2	1.87392946	0.16421859
3	1.70971087	0.28662549
4	1.42308538	0.12097267
5	1.30211272	0.00529146
6	1.29682126	0.08463526

7	1.21218599	0.0236553
8	1.18853069	0.12199547
9	1.06653522	0.02568666
10	1.04084856	0.04604182
11	0.99480674	0.00754404

Appendix C

Table C. 1. Eigenvalue by each factor from principal component analysis for the prevalent dietary patterns among 40-79 year old Canadians.

	Eigenvalue by Each Factor
Factor1	3.4495174
Factor2	1.8944553
Factor3	1.6717347
Factor4	1.452964
Factor5	1.2855948
Factor6	1.2242435
Factor7	1.1927187
Factor8	1.1656881
Factor9	1.094429
Factor10	1.0886178

Table C. 2. Orthogonal Transformation Matrix from principal component analysis for the prevalent dietary patterns among 40-79 year old Canadians.

	Orthogonal Transformation Matrix									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	0.54247	-0.46309	0.32495	0.28118	-0.23228	0.20576	-0.32747	0.04315	-0.28774	0.13571
2	0.04136	0.36521	0.55068	-0.02796	0.54173	0.43541	0.08063	0.19882	-0.01955	0.17723
3	0.06059	0.12363	0.11088	0.60343	0.30599	-0.54468	0.00297	-0.35431	0.07332	0.28878
4	-0.07592	-0.00087	-0.52891	0.45546	0.1557	0.1886	-0.16443	0.61352	0.08462	0.19137
5	0.0289	0.52745	-0.1645	0.2769	-0.46725	0.46339	0.06154	-0.39117	-0.05638	0.15554
6	-0.06785	-0.33751	0.14761	-0.01793	-0.24614	0.08289	0.52478	0.07876	0.48456	0.5249
7	-0.17042	0.25769	0.08207	-0.33478	-0.25058	-0.31733	-0.32719	0.22228	-0.30039	0.61283
8	-0.52994	0.0181	0.46017	0.29321	-0.31198	-0.01285	-0.35491	0.14483	0.31504	-0.27825
9	0.48437	0.22172	-0.07269	-0.23664	0.00673	-0.05025	-0.42232	-0.02732	0.68766	0.02015
10	0.38032	0.35898	0.16276	0.13244	-0.30924	-0.33294	0.41068	0.47572	-0.0629	-0.27759